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PWGSC Contract No. W7711-7-7404/01-SV

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March 2001

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Function Analysis of TIAPS, Update of CANTASS Functionality and Human Factors Review of OMI Design for Sonar Combat Systems

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On behalf of
DEPARTMENT OF NATIONAL DEFENCE

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14. ABSTRACT

(U) This report covers a number of Human Factors (HF) issues relating to the role of the operator and the operator machine interface (OMI) in sonar processing. The first section of the report updates an existing function analysis of the CANadian Towed Array Sonar System (CANTASS) to incorporate ongoing operational functions that have emerged since the original analysis was conducted. The second section of the report reviews relevant literature that addresses design issues for the OMI of sonar combat systems. No specific guidelines were found that could be directly applied to the design of new sonar systems. However, some useful generic principles for the display of tactical information, for representing the underwater environment, for data visualisation and for supporting military command decision-making were obtained.

The third section of the report outlines a function analysis of the Towed Integrated Active Passive Sonar (TIAPS) system based upon its present state of development, reviews HF considerations of the TIAPS OMI and examines core functions. These include configuring the system, monitoring, evaluating and refining automated processes, analysing the "truth" concerning auto-detected contacts, building and monitoring the tactical picture and building and maintaining the Under Water (UW) recognised maritime picture (RMP). Specific OMI design issues are identified in areas with respect to display design, tools to support contact analysis, workstation configuration, software navigation and communication of spatial information. The analysis also examined broader and more fundamental problems concerning the relationship between the operator and automated system functions, notably trust in automation and the need to for operators to comprehend limitations in the data produced by automated detectors and trackers. Finding solutions to the human-system problems associated with more automation is identified as an equally important research concern as developing the robust algorithms that make automation feasible.

The final section deals with future research and development activities that may be required to support ongoing TIAPS evolution from technology demonstrator to operational service. Recommended areas for research include operator interaction with automated systems, allocation of function among the system and team members, improving the capability of the operator to visualise the tactical UW environment and function and design issues concerning the role of the tactical display.

15. KEYWORDS, DESCRIPTORS or IDENTIFIERS

(U) Operator Machine Interface; CANTASS; TIAPS; function analysis; sonar combat systems

Abstract

This report covers a number of Human Factors (HF) issues relating to the role of the operator and the operator machine interface (OMI) in sonar processing. The first section of the report updates an existing function analysis of the CANadian Towed Array Sonar System (CANTASS) to incorporate ongoing operational functions that have emerged since the original analysis was conducted. The second section of the report reviews relevant literature that addresses design issues for the OMI of sonar combat systems. No specific guidelines were found that could be directly applied to the design of new sonar systems. However, some useful generic principles for the display of tactical information, for representing the underwater environment, for data visualisation and for supporting military command decision-making were obtained.

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Résumé analytique

Le présent rapport traite d'un certain nombre de facteurs humains (FH) relatifs au rôle de l'opérateur et de l'interface opérateur-machine (IOM) en traitement sonar. La première partie de ce rapport présente une mise à jour d'une analyse de fonction précédente portant sur le Système sonar à réseau remorqué canadien (CANTASS) visant à intégrer des fonctions opérationnelles qui ont vu le jour depuis la période où l'analyse précédente avait été effectuée. La deuxième partie de ce rapport passe en revue la littérature pertinente qui traite des questions de conception des IOM des systèmes sonar de combat. Aucune ligne directrice pouvant s'appliquer directement à la conception de nouveaux systèmes sonar n'a été relevée. Par ailleurs, quelques principes généraux utiles en matière d'affichage de renseignements tactiques, de représentation de l'environnement sous-marin, de visualisation des données et de soutien à la prise de décision dans le domaine du commandement militaire ont été formulés.

La troisième partie du rapport décrit une analyse des fonctions du Sonar remorqué intégré actif passif (TIAPS) fondée sur son degré de développement actuel et elle examine des facteurs humains en jeu dans l'IOM du TIAPS et ses fonctions essentielles. Ces fonctions comprennent la configuration et la surveillance du système, l'évaluation et le perfectionnement des processus automatisés, l'analyse de la « véracité » des contacts détectés automatiquement, l'élaboration et le maintien du tableau tactique et le maintien du Tableau de la situation maritime (TSM) sous-marine. Des questions de conception spécifiques à l'IOM sont soulignées dans des domaines comme la conception de l'affichage, les outils pour l'analyse des contacts, la configuration des postes de travail, la navigation dans le logiciel et la communication d'information spatiale. Cette analyse a aussi porté sur le problème, plus vaste et plus fondamental, de la relation entre l'opérateur et les fonctions automatisées du système, en particulier la confiance accordée par l'opérateur aux fonctions automatisées et le besoin qu'a l'opérateur de comprendre les limites des données produites par les détecteurs et les dispositifs de poursuite automatisés. La découverte de solutions aux problèmes associés à l'accroissement de l'automatisation sur le plan de la relation entre les persones et les systèmes est relevée comme étant un sujet de recherche aussi important que l'élaboration des algorithmes robustes qui rendent possible l'automatisation.

La section finale traite des activités de recherche et développement futures qui pourraient être requises afin d'aider à l'évolution du TIAPS du statut de démonstrateur de technologie au statut de service opérationnel. Les domaines de recherche recommandés comprennent l'interaction entre l'opérateur et les systèmes automatisés, l'allocation des fonctions entre le système et les membres de l'équipe, l'amélioration de la capacité de l'opérateur à visualiser l'environnement tactique sous-marin, ainsi que les questions de fonction et de conception en ce qui concerne le rôle de l'affichage tactique.

Executive Summary

This report is in four parts and covers a number of Human Factors (HF) issues relating to the role of the operator and the operator machine interface (OMI) in sonar processing. The first part of the report updates an existing function analysis of the CANadian Towed Array Sonar System (CANTASS) to incorporate ongoing operational functions that were not uncovered as part of the original analysis. These functions are added onto the basic structure of the original analysis that remains substantially unchanged.

The second part of the report reviews relevant literature that addresses design issues for the OMI of sonar combat systems. The literature was divided into categories that addressed sonar systems, military combat systems, military and non-military, general, design guidelines and data visualisation. No specific guidelines were found that could be directly applied to the design of new sonar systems. However, some useful generic principles for the display of tactical information, for representing the underwater environment, for data visualisation and for supporting military command decision making were obtained.

The third part of the report outlines a function analysis of the Towed Integrated Active Passive Sonar (TIAPS) system based upon its present state of development. The operational goal of TIAPS is defined as building and maintaining the underwater tactical picture. The specific functions that support this are decomposed down to sufficient levels to understand the major tasks involved and associated function descriptions and flow diagrams are provided in an Annex. The second section of this part provides a HF review of the TIAPS OMI and examines core functions. These functions involve: configuring the system, monitoring, evaluating and refining automated processes, analysing the "truth" concerning auto-detected contacts, building and monitoring the tactical picture and building and maintaining the Under Water (UW) recognised maritime picture (RMP). Specific OMI design issues are identified in areas with respect to display design, tools to support contact analysis, workstation configuration, software navigation and communication of spatial information. The analysis also examined the broader problem concerning the relationship between the operator and automated system functions. Issues such as operator trust in automated functions, the implications of automation on the role of the operator and assignment of functions to human or system are discussed.

The final section deals with future research and development activities that may be required to support ongoing TIAPS evolution from technology demonstrator to operational service. Recommended areas for research include operator interaction with automated systems, allocation of function among the system and team members, displaying the tactical UW environment, function and design issues concerning the role of the tactical display.

It is concluded that the function analysis of TIAPS is timely and not only provides a foundation for understanding the system from an operational perspective, but also serves as a framework for future analyses. It is recommended that further HF analyses be integrated with the build and test development process to ensure that OMI and operator function issues receive their own focus of development beyond the current emphasis on ensuring that the underlying technological concepts

are sound and can be implemented. Future analyses will also be required to evaluate the emerging tool suite in terms of its utility and usability to ensure that it will support the core functions of detection, analysis, classification and tactical decision making. Task network simulation is recommended as a method for evaluating design options as well as investigating the complex balance between operator tasks and automated system functions.

Résumé

Le présent rapport en quatre parties traite d'un certain nombre de facteurs humains (FH) relatifs au rôle de l'opérateur et de l'interface opérateur-machine (IOM) en traitement sonar. La première partie de ce rapport présente une mise à jour d'une analyse de fonction précédente portant sur le Système sonar à réseau remorqué canadien (CANTASS) visant à intégrer des fonctions opérationnelles qui ont vu le jour depuis la période où l'analyse précédente avait été effectuée. Ces fonctions sont ajoutées à la structure de base de l'analyse originale, qui demeure essentiellement inchangée.

La deuxième partie de ce rapport passe en revue la littérature pertinente qui traite des questions de conception des IOM des systèmes sonar de combat. Cette documentation a été divisée en catégories correspondant aux systèmes sonar militaires et non militaires, aux aspects généraux, aux principes de conception et à la visualisation des données. Aucune ligne directrice pouvant s'appliquer directement à la conception de nouveaux systèmes sonar n'a été relevée. Par ailleurs, quelques principes généraux utiles en matière d'affichage de renseignements tactiques, de représentation de l'environnement sous-marin, de visualisation des données et de soutien à la prise de décision dans le domaine du commandement militaire ont été formulés.

La troisième partie du rapport décrit une analyse des fonctions du Sonar remorqué intégré actif passif (TIAPS) fondée sur son degré de développement actuel. L'objectif opérationnel du TIAPS est défini comme étant l'élaboration et le maintien du tableau tactique sous-marin. Les fonctions spécifiques qui prennent en charge cet objectif sont décomposées en un nombre de niveaux suffisant pour comprendre les principales tâches requises et une annexe comporte les descriptions des fonctions ainsi que les ordinogrammes connexes. La deuxième section de cette partie comporte un examen des facteurs humains en jeu dans l'IOM du TIAPS et de ses fonctions essentielles. Ces fonctions comprennent la configuration et la surveillance du système, l'évaluation et le perfectionnement des processus automatisés, l'analyse de la « véracité » des contacts détectés automatiquement, l'élaboration et le maintien du tableau tactique et le maintien du Tableau de la situation maritime (TSM) sous-marine. Des questions de conception spécifiques à l'IOM sont soulignées dans des domaines comme la conception de l'affichage, les outils pour l'analyse des contacts, la configuration des postes de travail, la navigation dans le logiciel et la communication d'information spatiale Cette analyse a aussi porté sur le problème, plus vaste, de la relation entre l'opérateur et les fonctions automatisées du système. Il est aussi question d'autres sujets comme la confiance accordée par l'opérateur aux fonctions automatisées, les conséquences de l'automatisation sur le rôle de l'opérateur et l'affectation de fonctions aux personnes ou aux systèmes.

La section finale traite des activités de recherche et développement futures qui pourraient être requises afin d'aider à l'évolution du TIAPS du statut de démonstrateur de technologie au statut de service opérationnel. Les domaines de recherche recommandés comprennent l'interaction entre l'opérateur et les systèmes automatisés, l'allocation des fonctions entre le système et les membres de l'équipe, l'affichage de l'environnement tactique sous-marin, ainsi que les questions de fonction et de conception en ce qui concerne l'affichage tactique.

On conclue en affirmant que l'analyse de fonction du TIAPS est adéquate et qu'elle ne constitue pas seulement un fondement pour la compréhension du système d'une perspective opérationnelle, mais qu'elle sert aussi de cadre de travail pour des analyses à venir. Il est recommandé que les analyses futures des facteurs humains soient intégrées au processus de développement des versions de développement et des essais pour que l'on accorde plus d'importance au développement de l'IOM et des fonctions de l'opérateur, au-delà de celle qui leur est accordée lorsqu'on s'assure que les principes technologiques sous-jacents sont valables et peuvent être mis en oeuvre. D'autres analyses seront par ailleurs requises afin d'évaluer l'ensemble d'outils à venir sur les plans de son utilité et de son utilisabilité afin de s'assurer qu'il soutiendra les fonctions essentielles de détection, d'analyse, de classification et de prise de décision tactique. La simulation de réseaux de tâches est recommandée comme méthode d'évaluation d'options de conception ainsi que l'étude de l'équilibre complexe entre les tâches de l'opérateur et les fonctions automatisées du système.

Table of Contents

1. Introduction

1.1 Background

This report is the result of work carried out under PWGSC Contract No. W7711-7-7404/01-SV

Call Up: 7404-12 under the Scientific Authority of Sharon McFadden at DCIEM. The report addresses the following requirements in the Statement of Work (SOW):

> *Item #3: "Review existing CANTASS task analysis" (update function analysis to include current operational concept of CANTASS)*[1]

> *Item#4: "Develop preliminary function analysis based on the YARD analysis and update it to include new functionality provided by TIAPS and SIMS".*

This initial tasking has been subsequently narrowed in discussion with the Scientific Authority to include only the Towed Integrated Active Passive Sonar (TIAPS) system at this point in time, since the evolution of the Sonar Integrated Management System (SIMS) program is ongoing and not at the point where a meaningfully representative function analysis can be performed. Further, given that a significant part of the functionality of the proposed functionality of SIMS has been incorporated into TIAPS, the report is also relevant to the development of SIMS.

> *Item #6: "Review available documentation and background literature relevant to the design of OMI's for sonar/combat systems and prepare a short summary report on literature reviewed."*

> *Item#8: "Prepare a report covering a usability review of TIAPS, usability of current designs, limitations of the system, suggestions for improvements and potential topics for long term research*[2]

1.2 Report Organisation

The report is organised into the following sections, which in many cases can be read independently of other sections:

- Summary literature Review of Operator Machine Interface (OMI) issues for sonar systems
- Extension of YARD CANadian Towed Ararray Sonar System (CANTASS) function analysis to include current operations
- Function analysis of TIAPS

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[1] The latter tasking was appended in discussions with the Scientific Authority

[2] Again, in consultation with the Scientific Authority, it was agreed that given the current state of TIAPS system development a usability analysis would be premature. Hence, as an interim step, a preliminary outline of gross, critical tasks would be conducted.

- Critical task analysis, human factors (HF) heuristic review of TIAPS and recommendations for research and development
- Discussion

1.3 Objectives

The general objectives are:

- To provide a base reference framework for existing TIAPS functions under development that will also allow future functions to be integrated
- To identify critical operator tasks that will provide a focus for research efforts to provide appropriate HF input to the design process.
- To identify areas of functionality where the design of the OMI will need to be sensitive to specific operator requirement or limitations
- To identify areas of the TIAPS OMI that will require particular research and development effort.

1.4 Glossary

AAWC	Anti Air Warfare Co-ordinator
ADAC	Acoustic Data Analysis Centre
AOP	Area of Operation
ASW	Anti-Submarine warfare
ASWC	Anti-Submarine Warfare Commander
C2	Command and Control
CANTASS	CANadian Towed Array Sonar System
CCS	Command Control System
CDC	Computing Devices Canada
CISTI	Canada Institute for Scientific and Technical Information
CO	Commanding Officer
COP	Common Operational Picture
COTS	Commercial Off The Shelf
CPF	Canadian Patrol Frigate
DCIEM	Defence and Civil Institute for Environmental Medicine
DII	Defence Information Infrastructure
DREA	Defence Research Establishment Atlantic

DV	Data Visualisation
GCCS	Global Command and Control System
GIS	Geographical Information System
HF	Human Factors
MOP	Measure of Performance
MPA	Maritime Patrol Aircraft
NTDS	Naval Tactical Display Symbols
NTIS	National Technical Information Service
OMI	Operator Machine Interface
OODA	Observe, Orient, Decide, Act
OR	Operations Room
ORO	Operations Room Officer
PLA	Passive Localisation Assistant
RMP	Recognised Maritime Picture
SCS	Sonar Control Supervisor
SIMS	Sonar Integrated Management System
SME	Subject Matter Expert
SonOp	Sonar Operator
SOW	Statement of Work
TASREPS	Towed Array Sonar Reports
TasSup	Towed array supervisor
TG	Task Group
TP	Tactical Picture
TMA	Target Motion Analysis
TIAPS	Towed Integrated Active Passive Sonar
UW	Underwater

2. Summary Literature review of OMI issues for sonar systems.

2.1 Background

The work undertaken below is guided by the Statement of Work, item #6, which states:

> "Review available documentation and background literature relevant to the design of HMI's for sonar/combat systems and prepare a short summary report on literature reviewed."

The present literature review should be read in the context of an earlier, more detailed review conducted for DREA (Matthews, Greenley and Webb, 1994), which contains a more extensive discussion of the literature.

In reviewing the scope of the review with the Scientific Authority, it was decided that a limited search be also conducted in the area of data visualisation, since there was a likelihood that future sonar and combat systems would embrace aspects of data fusion and other aspects of data abstraction. It was noted that existing guidelines that were available did not provide recommendations in this area. A second outcome of the review of the scope of the search was the decision not to seek or review generic windowing system or platform-independent guidelines.

2.2 Objectives

The overall goals of the literature review are (1) to provide relevant documentation for system developers to consult as required in order to optimise the sonar operator interface in new and emerging systems and (2) to provide a basis for a heuristic review of the TIAPS OMI currently under development.

2.3 Organisation of this section

A complete listing of all of the relevant references that were obtained and examined is provided in Annex A.

The initial section describes the methodology used for the report, followed by a section that provides a brief commentary upon the most useful subset of references that were found. These references are organised into the following sub-categories:

- Sonar systems
- Military combat systems
- General military and relevant non-military guidelines
- Data visualisation

The first three categories represent decreasing levels of system specificity concerning guidelines and recommendations. The final category is somewhat different in that it contains material that may be of relevance at any level of specificity.

After reviewing either an abstract or their content, papers and reports listed in the complete bibliography that were generally deemed to be of little relevance to the immediate project goals were not commented upon in these sections.

The literature review finishes with an overall summary and conclusions.

2.4 Search methodology

The aim of the literature review was to locate and review current literature in two areas:

1) Existing human factors guidelines or research reports relevant to the interface design of combat systems, in particular sonar systems.

2) Literature on data visualisation

2.4.1 Databases Searched

The searches were conducted using the Canada Institute for Scientific and Technical Information CISTI database (cat.cisti.nrc.ca) and National Technical Information Service (NTIS) (www.ntis.gov) as well as a library catalogue search of the Trellis system through the University of Guelph.

NTIS

NTIS is an agency for the U.S. Department of Commerce's Technology Administration. It is the official source for government sponsored U.S. and worldwide scientific, technical, engineering and business related information. The 400,000 article database can be searched for free at the www.ntis.gov. Articles can be purchased from NTIS at costs depending on the length of the article.

CISTI

CISTI stands for the. It is the library for the National Research Council of Canada and a world source for information in science, technology, engineering and medicine. The database is searchable on-line at cat.cisti.nrc.ca. Articles can be ordered from CISTI for a fee of approximately $12.

Trellis

Trellis is the catalogue for the Tri-University Group (TUG) of universities. It contains catalogues of book and journal sources from the University of Guelph, University of Waterloo and Wilfred Laurier University library systems.

2.4.2 Keywords

A set of keywords was developed with the goal of locating literature in the two areas described above.

Keywords intended to locate literature on interface guidelines were divided into four categories. Category 1 related to the sonar environment, category 2 was "interface related", category 3 was "user related" and category 4 was "guideline related".

For the data visualisation area of the search, words were divided into two categories, Category 5 was "visualisation related words" and category 6 was "modifiers".

The words in each category are listed in Table 1

Table 1: Keywords used for literature search

Area 1- Interface guidelines

Category 1	Category 2	Category 3	Category 4
Sonar environment	**Interface related**	**User related**	**Guideline related**
Sonar OR command and control OR C2 OR C3 OR C4 or C3I OR information systems OR combat systems OR combat information center OR anti-submarine OR ASW OR defense OR defence OR navy OR naval OR military OR marine OR ship OR operations room OR subsurface war OR subsurface warfare OR maritime OR submarine OR NATO	Interface OR display OR interaction	User OR human OR man-machine OR human-computer OR man-computer OR human-machine OR HCI OR HMI OR OMI OR human systems integration	Guidelines OR rules OR requirements OR recommendations OR design OR specifications OR standards OR style guide

Area 2—Data Visualisation

Category 5	Category 6
Visualization	**Modifiers**
Visualization or visualisation	Information OR command OR data OR battlespace OR sonar

2.5 Search strategy

The initial approach to setting keyword combinations for the search was as follows:

Area 1: Interface Guidelines

Search:

Category 1 and Category 2,

Category 1 and Category 3,

Category 1 and Category 4

If this generated too many results, then search:

Category 1 and Category 2 and Category 3

Category 1 and Category 2 and Category 4

Category 1 and Category 3 and Category 4

If this generated too many results, then search:

Category 1 and Category 2 and Category 3 and Category 4

Area 2-Data Visualisation

Search: *Category 5 and Category 6*

In practice, because many of the categories produced few or no results, or many irrelevant results, the searches were combined and conducted together. For guideline related references the following search was used:

(Category 1 OR Category 3) AND (Category 2 OR Category 4))

and for data visualisation references, the following search was used:

(Category 5 OR Category 6)

2.6 Search results

The relevant items selected from each search source are shown below in Table 2 below.

Table 2: Numbers of articles found using the above search parameters.

(Note: the first number is the total number of articles, second number is those deemed to be relevant)

	Guideline-related	Visualisation-related
CISTI	371-->2	388 -->4
NTIS	200-->3	200-->18
Trellis	22--> 8	26 --> 10
Total	13	32

Many of the references resulting from the searches were determined to be irrelevant, either immediately by the title or after review of the abstract. Some references were located in both CISTI and NTIS, or both Trellis and CISTI. In the above Table these references are shown under NTIS or Trellis, and not under CISTI. The NTIS searches were limited to 200 references because of the nature of the NTIS search interface.

Most of the references located through CISTI and NTIS were gathered from the DCIEM Scientific Authority or through the DCIEM library. References from Trellis were gathered through the University of Guelph.

2.7 Other reference sources

In addition to the references found through the online database searches, some additional applicable references were reviewed. There were several sources for these references: interface guideline sites on the World Wide Web, references already available in-house at Human*systems* and references provided by navy personnel or the DCIEM scientific authority. In practice, many of these latter references tended to be more relevant to the goals of the project than those found by the keyword search and served as the basis for finding additional sources through the usual "snowballing" process.

The search strategy became modified somewhat after the opportunity to review at first hand some aspects of the prototype TIAPS functionality. It was discovered that one core aspect of the TIAPS interface and functionality employed a tactical display on which processed sonar information could be displayed alongside other elements of the tactical situation and environmental data. Therefore, late in the search it was decided to extend the search in a limited manner to gather information on already available guidelines relevant to combat tactical displays. This extended search was conducted exclusively using snowballing methodology.

2.8 Commentary on selected references

The references below represent a selected subset of the references in the Annex A, chosen for their appropriateness to the goals of the review. In the case of the section on data visualisation, many of the references did not provide any usable guidelines or data that would be of value for immediate adoption into the TIAPS design and development process. However, the area of data visualisation is probably going to be of key importance not only to sonar operators, but also to other navy personnel engaged in working with new generations of combat systems. These systems will no doubt involve functionality that incorporates data fusion, data modelling and large-scale data management in support of new approaches to enhance military decision making. Therefore, it was decided to provide a brief overview of some of the major work published in the area of data visualisation in recent years to provide a reference base for scientists and system developers who are beginning to think about issues of data visualisation in combat systems.

In each sub-section the material is organised alphabetically. Papers or reports of particular importance are prefaced with

2.8.1 Sonar systems

Benke, K. K., & Hedger, D. F. (1996). *Improving Feature Perception in Sonar Displays by Contrast Normalisation and Enhancement.* Canberra, Australia: Defence Science and Technology Organisation.

This paper provides methods for compressing and digitising sonar data through gamma compensation to optimise luminance profile on sonar displays. The method is said to improve the operator's perception of seabed features and improves search reliability during surveillance.

Doll, T. J., & Hanna, T. E. (1989). *Effects of Bimodal Displays on Sonar Target Detection.* Groton, CT, USA: Naval Submarine Medical Research Lab.

This report examines the impact of supplementing lofargram type displays with redundant auditory signals on sonar target detection. Finds a 1.1 dB improvement for the bimodal display format and some reduction of the effects of uncertainty on detection. Enhanced spatial compatibility between the visual and auditory displays produced no measurable effects. But this may have been due to the fact the type of compatibility that was selected had not been optimised. Further the seemingly more compatible relationship between a dichotic auditory display and a visual display did not improve performance over a diotic (less compatible) display.

Douglas, H. J., & Zannelli, D. (2000). *Display and Control Commonality Initiative Among Undersea Warfare Sonar Systems.* Newport, RI: Naval Undersea Warfare Center.

This report outlines some standards initiatives for the OMI by the Sonar Systems in Undersea Warfare group to provide commonality across systems. Some data are provided on user testing of interface options concerning input mode and menus. Although this report does not list recommenced standards *it does provide useful references to some standards documentation.*

Galvin, L. F. (1991). *Human Factors Engineering in Sonar Visual Displays.* Massachusetts Institute of Technology, Cambridge, MA, USA.

This is oriented towards designing an OMI for a remotely operated underwater vehicle. Of interest, but perhaps limited value, is a prototype colour scheme to code altitude (depth) bands. However, since the author does not provide photometric values for the coded elements this may mean that it will be difficult to adopt the coding scheme to other applications and display environments.

Handbook 5: *Guidelines for Maritime Information Management.* Management of Organic and Non-Organic Information in the Maritime Environment, Command, Control and Communications Committee, AUSCANNZUKUS, April 1997.

This document provides *an important high level overview of generic information management needs* for maritime command and control. Useful sections for present purposes include:

- A description of basic naval command system characteristics
- A list of system user requirements
- Requirements for the maritime tactical picture

- Sensors and sensor management
- Classification
- Track quality and management
- Data fusion

Some specific points of reference that will need to be considered in developing the TIAPS system in conformity with the guidelines are:

3.9.2.2.a	Procedures for track management
3.9.3.5	Sensor management
3.9.4	Classification (in particular section on classification confidence)
3.9.5.3	Track quality
3.9.5.4	Factors affecting procedures
3.9.6.3	Data confidence
3.9.7	Data fusion (especially sub-sections 7.4, 7.5, 7.6, 8.4)

It should be remembered that since the document is a high level overview, no specific guidelines are provided on the OMI that will be required to achieve the above.

Holliday, T. M. (1998). *Real-Time 3D Sonar Modeling and Visualization*. Unpublished Master's, Naval Postgraduate School, Monterey, CA.

This thesis discusses mostly technical and computational issues with respect to transforming acoustic data into 3D representations.

The section on visualisation attempts to provide some guidance on how to map high dimensionality sonar data onto two dimension displays and suggests that there is no right answer.

Comment:

Some very general recommendations are made on mapping that are probably insufficiently detailed to be of immediate utility for interface design.

Kobus, D. A., & Lewandowski, L. (1991). *Reported Modality Preferences of Sonar Operators*. San Diego, CA: Naval Health Research Center.

This empirical study shows that sonar operators prefer a visual over an auditory presentation of data, and believe that they are better in the visual mode. This corresponds to their general modality preferences for non-sonar tasks. Suggests some design flexibility to allow for the minority of operators who prefer the auditory mode.

Manning, R. & Lankester, M. *Sonar world picture compilation*. (U). *Proceedings of the TTCP Symposium Co-Ordinated Maritime Battlespace Management*, San Diego, CA, May 1999 (UK Restricted)

This text provides some useful descriptions of operator aids for sonar classification to reduce operator workload and to enhance prioritisation of contacts and conflict resolution.

McFadden, S. M., Giesbrecht, B. L., & Kalmbach, K. C. (1995). ***Effect of Monitor Type and Display Orientation on the Detection of Lines on a Simulated Passive Sonar Display.*** **Downsview, ON, Canada: Defence and Civil Institute for Environmental Medicine.**

McFadden, S. M. Zulauf., M. (1995). ***Display Factors Affecting The Visibility of Information on a Simulated Passive Sonar Display.*** **Downsview, ON, Canada: Defence and Civil Institute of Environmental Medicine.**

These empirical studies show that displaying lofargrams with the time history along (as opposed to current practice which is across, i.e. top to bottom) the scan lines yields improved operator detection performance (12-18%). Result holds for both mono- and multi-chrome monitors. Negligible effects of reduced luminance output (NB - this was only degraded 20% in the study).

Undersea Warfare Sonar Systems Control and Display Standards and Conventions (September 25, 1998). Available: www.ocwg.uswinfo.com.

This document provides a comprehensive catalogue of OMI recommendations for undersea warfare (USW) systems. In general, the overall recommended style follows standard commercial practices for window based operating systems (e.g. OSF Motif, Windows NT) and assumes a display system with a 1280x1024 capability. Much of the specification is derived from the user interface specifications for Defence Information Infrastructure (DII).

Comment:

This will be an **essential document** to assist the Computing Devices Canada Inc (CDC) design team in many aspects of the detailed OMI development and against which to assess the degree to which TIAPS meets recommended standards. In addition to providing commonly understood conventions for window design, navigation and dialog boxes, it also provides specific guidance on USW functions, including ship data and sensors, tactical symbology (MIL-STD 2525A), acoustic cursors and acoustic displays.

Caveats and limitations

1. The guide recommends the use of grayscale only for lofargrams - hence no colour guidelines are provided
2. Colour application recommendations for display elements are not provided in appropriate photometric units (the guide only provides RGB values and colour names).
3. No specific considerations are given to the constraints on the OMI that may be produced by local environmental lighting.
4. No considerations are given to support for the user's mental model in switching between various display modes.

5. The guide recommends against the use of "reverse video" for text on the grounds of lower legibility and increased operator fatigue. Assuming that this means text characters that have higher luminance than the background (positive contrast), this recommendation must be questioned. The statement does not reflect recent research in this area, which has shown equivalent legibility for positive contrast displays. Further, when using coloured text and coloured backgrounds, the term reverse video is inapplicable.
6. No specific guidelines provided on appropriate coloured text and background combinations.(e.g. with delta Yu'v' colour space recommendations)
7. The adherence to the Motif/Windows NT style for the application of colour to window elements creates problems for designing a colour style that is appropriate to the USW operating environment.
8. No consideration is given to over-the-shoulder viewing needs by other team members.

Woollings M.J. *Automatics vs. operators in active sonar.* (U). Proceedings of the TTCP Symposium Co-Ordinated Maritime Battlespace Management, San Diego, CA, May 1999 (UK restricted).

The author defines the major problem in active sonar as follows: " *the combat system will never be able to cope with the tracks produced by an active sonar operating in littoral waters without an intelligent filter acting on the raw sonar data*". The author describes a simulation model to reduce false alarm rates while maintaining detection and provides data on how the model compared with an actual operator.

Comment:

This will be of use to system designers who are engaged in implementing automatic detection algorithms for active sonar.

2.8.2 Military combat systems

A large number of guidelines and research reports in this area have appeared in recent years, some developed independently by separate branches of the military or independent contractors and others developed sequentially by the US military to rationalise and integrate knowledge. The majority of these reports provide generic guidelines for OMI design for military systems, which is not the primary focus of the existing review (i.e. sonar combat systems). Examples of these guidelines are: *Department of Defense Technical Architecture Framework for Information Management:* (1996), Engel, and Townsend (1989), *Carlow: Human Computer Interface Guidelines* (1992). These may be generally useful as a reference source for system developers of naval combat systems and defence scientists but are not commented upon here.

The small number of papers that are commented upon on this section provide some specific detailed information, not to be found in guidelines, and deemed to be directly relevant to OMI issues in combat systems design.

Hair, D. C. P., K. (1993). ***User Interface Issues in Real Time Decision Support Systems.*** **San Diego, CA: Naval Command, Control and Ocean Surveillance Center.**

This research was part of the TADMUS project. For real time decision making support, automatic critiquing of decisions is seen as a preferred approach over decision makers interacting with the system. Tools have been developed to support both recognition primed decision making (RPD) or explanation based decision making. The goal is to provide information in a way that matches the user's decision making approach. On the basis of limited empirical studies, the author suggests eliminating features of decision support that require frequent user interaction. This results in "severe simplification of tool capabilities".

An alternate approach is to incorporate a model of the user into the system. The model will then analyse the user's information needs, supply the appropriate information and warn of possible errors. At present, this approach is not being explored.

The author is also trying an approach which (1) structures displays in a manner that provides suggestions about alternative conclusions, or (2) finds template matches appropriate to RPD or (3) provides a record of historical information to prevent users from losing track of relevant data.

The overall goal is to reduce negative effects of cognitive biases in decision making.

Comment:

References in the area of real time decision support should probably be followed up since this may be of value in assisting design for some of the higher level OMI functions that are likely to emerge for TIAPS and other combats systems.

Laxar, K., & Van Orden, K. F. (1994). ***Symbology Optimization and Display Assessment (SODA) Project:: Minimum Size for Color Coded NTDS and NATO Symbols (NSMRL Report 1194*****): Naval Submarine Medical Research Laboratory.**

Using 3 symbol sizes:19/22, 28/32, 38/40 (NTDS/NATO) arcmin in a multidistractor search task (10 or 40).For NATO symbols search time for 19' increased by about 23% over 28' targets and 57% over 38' targets.

For Naval Tactical Display symbols (NTDS) search time for 22' increased by about 25% over 32' targets and 37% over 40' targets.

NTSD smallest targets faster by about 60% faster than NATO and fewer errors.

Effect of distractor set size much larger for NATO targets and small targets.

Limitations:

Relatively simple symbol format (no additional codes or text)

Ambient illumination values and luminance values not provided, hence the user cannot calculate delta Yu'v' which is important for establishing generality of the result to other colour/luminance conditions.

Osga, G. (1995). *Combat Information Center Human-Computer Interface Design Studies* (Final TD 2822). San Diego, CA: Naval Command, Control and Ocean Surveillance Center RDT&E Division.

This report provides a comprehensive review analysis of the AEGIS OMI in the context of the Anti Air Warfare Co-ordinator (AAWC) position. The report outlines:

- Detailed recommendations on general and specific design concepts with respect to displays, controls and workstation configuration
- Useful methods on test and evaluation
- Selected human performance criteria

Comment:

This report provides an essential guide against which to evaluate current systems as well as informing the design of future systems. Many of the suggested design concepts may serve as useful models and examples for the TIAPS OMI.

The strengths of the report are in its careful analytic approach to the problem, using data from task analysis to inform design decisions and evaluating prototype design options using valid tasks and empirical data.

Particularly useful sections pertain to:

- Displays for system status
- Variable action buttons
- Touch panel design
- Comparison of input methods (trackball, mouse, touchscreen)
- Workstation configuration
- Tactical displays and symbology

Osga, G., & Keating, R. (1994). *Usability Study of Variable Coding Methods for Tactical Information Display Visual Filtering* (Final TD 2628). San Diego, CA: Naval Command, Control and Ocean Surveillance Center RDT&E Division.

Variable coded symbology is seen as a way of providing redundant colour and shape coding to facilitate data extraction from complex tactical displays. The additional coding served as a way for operators to rapidly selectively filter displayed elements and enhance speed and accuracy of performance.

Operators performed a task involving a tactical display with many tracks for which they were required to develop filters to categorise track types. High face validity to actual tactical displays is apparent.

Comment:

The methodology may be useful for future studies to evaluate data fusion techniques.

Van Orden, K. F., Nugent, W., La Fleur, B., & Moncho, S. (1999). ***Assessment of Variable Coded Symbology Using Visual Search Performance and Eye Fixation (Final 99-4).*** **San Diego, CA: Naval Health Research Centre.**

Found faster visual search and fewer distractor errors with either colour coded NTDS symbols or prominent colour block filled NATO symbols. Recessed NTDS gray symbols produced the slowest times. (NB best case to worst case is 2.1 secs versus 4.2 secs. NATO colour filled superior to next best condition by about 38%.

Limitations:

No photometric data are provided.

2.8.3 General military and relevant non-military publications

Since this is a very broad category and the large number of published articles may only have limited direct relevance to the goals of this project, search in this category was given a lower priority and strictly limited to recent publications that would be of immediate use to system developers.

Brasseur, P. D., & Nihoul, J. C. J. (1993, May 1993). ***Data assimilation : Tools for Modelling the Ocean in a Global Change Perspective*****, Liege, Belgium.**

This provides mostly technical aspects of calculating and displaying ocean temperature/space/depth information, but some interesting graph examples of modelling complex data.

Levkowitz, H. (1997). ***Color Theory and Modeling for Computer Graphics, Visualization, and Multimedia Applications*****. Boston: Kluwer Academic Publishers.**

This is a useful reference source for calibration of colour displays, metrics for creating perceptually uniform colour scales and generating displays whose colours are stable and device independent.

Some empirical data on "blob detection" show that monochromatic grey displays yield superior performance to colour.

2.8.4 Data Visualisation

Note: abbreviated to DV in the following section

Bajaj, C. (1999). ***Data Visualization Techniques*****. Chichester ; New York: Wiley.**

Comment:

The contributed chapters all deal with technical aspects of generating visualised representations from data sources. There is no discussion of guidelines for interfaces or which representations are better suited for different types of data and applications, nor discussion of human comprehension and understanding. The book does provide a wealth of coloured examples of different visualisation representations.

Of interest, the author states some fundamental principles or goals that should drive visualisation. These are:

- Deeper understanding of data
- Rapid pruning of useless data
- Rapid focus on necessary information
- Comprehending the science or circumstances behind the data
- Use of motion and other techniques such as simulated depth, surface texture and colour to bring out hidden or important aspects of data.
- Use of motion for dynamic data.
- Provide interactive manipulation of data.

Earnshaw, R. A., & Wiseman, N. (1992.). *An introductory guide to scientific visualization*. Berlin ; New York: Springer-Verlag.

This text provides some goals of DV which include:

- Visual data analysis
- Insights into high dimensional data
- Comprehension of large data sets

But no HF guidelines or recommendations are provided on how to achieve these.

While the book does provide some good colour examples of various visualisation techniques, the bulk of it is largely a compilation of descriptions of various commercial DV packages.

Gershon N. *Battlespace Visualisation Issues*. NATO RTO IST-20/WS-002 Workshop "Visualisation of Massive Military Datasets", June 2000, Defence Research Establishment Valcartier, Quebec, Canada.

This paper presents a brief conceptual overview of the major visualisation issues relating to battlespace visualisation. There is no specific military focus and the only information available in the paper is a single figure showing the various issues, without any accompanying text narrative. Note: the paper was reviewed as a Powerpoint printout and no accompanying, detailed text narrative was available.

Hearnshaw, H. M., 1948-, Unwin, D. J., & Information, A. f. G. (1994). *Visualization in geographical information systems*. Chichester, West Sussex, England ; New York.

While this book is generally oriented towards GIS it does provide some concepts of where DV might be generically useful. These are:

- Representation of time: duration, rate of change, slow and fast constants, chronological order, attribute order.
- Representation of data validity and uncertainty. (data quality)
- Interaction with data
- Multiple views for multiple users

The book does contain a modest section on HF issues in DV; overall it provides a disappointingly low level review of underlying visual and psychological processes.

Some of the general HF recommendations for data interactivity are:

- Provide fast and rapidly updated representations in response to user input.
- Ensure data are displayed in concepts understood by user.
- Provide easy manipulation of properties of representation.
- Use of screen space optimally
- Provide basic tools such as: data probe (for local exploration and annotation), local viewing, ruler.
- Use "natural display mappings".

Hollands, J.G. *Command Visualisation*. NATO RTO IST-20/WS-002 Workshop "Visualisation of Massive Military Datasets", June 2000, Defence Research Establishment Valcartier, Quebec, Canada.

This paper provides a useful overview of how visualisation can support the understanding of data in a variety of command contexts and demonstrates how multiple views and pictorial representations improve upon standard tabular data formats. The focus of the paper is the process of developing a command visualisation testbed to enhance planning and operational functions. The paper provides some examples of avoiding designs that reduce perceptual bias and enhance the representation of the user's mental model. Note: the paper was reviewed as a Powerpoint printout and no accompanying, detailed text narrative was available.

IEEE Visualization 1998, IEEE Visualization 1999.

1998 IEEE Conference on Information Visualization : An International Conference on Computer Visualization & Graphics : Proceedings(July 29-31, 1998)., London, England.

1999 IEEE Symposium on Information Visualization (InfoVis'99) : proceedings(October 24-29, 1999)., San Francisco, California.

These proceedings provide mostly technical papers on numerical methods, algorithms and different display formats for DV. No HF content was found and there were no specific C2 examples.

Keller, P., & Keller, M. (1993). ***Visual Cues : Practical Data Visualization.*** **Los Alamitos, CA: IEEE Computer Society Press.**

This is a primer for designers involved in generating data images. It provides a simplistic overview of basic perceptual/display issues. Some general guidelines on use of colour are provided (pp28-31). The balance of the book contains a large number of specific examples of different applications.

The text provides a taxonomy of usages to which DV may be applied; for example: to identify, locate, distinguish, categorise, cluster, rank, compare, associate and correlate data. The authors suggest that where competing goals would lead to different DV solutions, the goals should be rank ordered.

Mulhearn, J.F., Encarnaceo, M., Shane, R.T. ***A collaborative visualization environment for submarine command and control.*** **Proceedings of the TTCP Symposium Co-Ordinated Maritime Battlespace Management, San Diego, CA, May 1999**

This paper provides some general concepts concerning 3D visualisation of undersea battlespace. It identifies some fundamental user requirements, which are: (1) a realistic display which is not defined by the authors in any detail, however in other sections of the paper they indicate that the display should comprise a 3-D display of perceived undersea battlespace with bathymetry, detection/counter detection regions and contacts volume of uncertainty) (2) the ability for the user to differentiate between realistic and approximated display and (3) the user to be aware of imprecision of approximated data.

NATO IST-13/TG-002. ***Visualisation in Massive Military Datasets.***

This report represents a comprehensive review of visualisation issues relating to military systems generally, not just large datasets as suggested by the title. The value of this report is that it takes a human factors perspective of the issues rather than looking at the underlying technology required to support visualisation.

The report commences by outlining a "reference model" for visualisation. This shows the critical role to be played by the visualisation process (the what) as a means of translating sensor, data or other processed information through computing engines (the how) to yield human understanding as a basis for action (the why). Among the examples of computer aids to visualisation provided in the first chapter, there is a useful illustration of how passive sonar data may be more readily understood using a an iso-surface representation of underwater topography and a school of fish. Further, it is suggested that the task of the sonar operator could be enhanced by the provision of improved visualisation methods to allow for the integration across the four dimensions of sonar data.

Chapter 2 provides an overview of selected human factors issues in visualisation and represents a useful reference for design engineers by drawing attention to the underlying human information processing requirements that should drive the technology of data visualisation. Major areas covered are human sensory and processing limitations and the four major ways in which humans use their sensory data. These are controlling/monitoring, alerting, searching and exploring. Each of these topics is examined at some depth and useful examples are provided. A major section of the chapter is devoted to an examination of ways in which data displays may be mapped to human sensory systems covering topics such as icon maps, symbols, patterns and clutter and reaching into more abstract representations involving metaphor and 3d representation.

Chapter 3 examines various data types and how they may be presented. Six major dimensions of data types are suggested:

1. Data acquisition - where are the data required, relative to when the display is needed?
2. Data sources - is there a single source or more than one independent source of data?
3. Data choice - can the user choose the data to be acquired?
4. Data identification - how are the individual data elements identified, by location or by label?
5. Data values - what kinds of values can the data have, analogue or categorical?
6. Data inter-relations - how does one data element relate conceptually to others? Does the value of one affect the meaning of another?"

Illustrations and examples are provided for each data dimension.

The latter half of the chapter looks at ways in which different types of displays (display timing, data selection, data placement and data values) may be matched onto the data categories, using "natural" mappings or more abstract cognitive transformations.

Chapter 4 provides an overview of some specific military applications including C2 information systems, network monitoring, event stream analysis, task analysis, representation of text and passive sonar. The C2 section outlines the standard OODA loop (observe, orient, decide, act) and integrates this process with the four modes of data visualisation outlined previously. An example is provided of how data visualisation through an iconic tactical map may assist the task of assessing danger over a two dimensional spatial area. The other section of primary interest for present purposes concerns issues surrounding the visualisation of passive sonar data. In this section, an analysis of the sonar operator's visualisation requirements is discussed in the context of the four modes of using sensory data.

Chapter 5 is of perhaps less relevance for present purposes, however, it provides an excellent overview of generic human factors issues in interface design.

Chapter 6 represents some core concepts for design for visualisation by providing the link between design approaches for data presentation and manipulation with the taxonomy of the six data dimensions. The chapter outlines requirements for data presentation systems and looks at issues such as fisheye views, attentional focus and navigation. Basic functions performed on the data include selection, organisation, manipulation and arranging. Other than the fisheye approach, few additional concrete examples are provided of specific ways to optimise the data representation.

Chapter 7 provides examples of a number of visualisation applications and techniques. Of most relevance to present purposes are the examples of the German xIRIS system for assisting situation visualisation and assessment and the UK Master Battle Planner, although these are more generally useful from a broad C2 perspective rather than impacting directly on design for sonar systems.

Although not the focus of the present literature analysis, it should be noted that Chapter 8 provides an excellent overview of performance measurement issues in data visualisation. This chapter may serve some future use in the development of specific MOPs to evaluate how effective data visualisation approaches may be compared against existing systems.

Chapters 9 and 10 summarise conclusions and make broad recommendations for researchers, developers and the military.

Post, F. H., & Hin, A. J. S. (1992). ***Advances in Scientific Visualization*****. Berlin: Springer-Verlag.**

This has limited usefulness; it provides a collection of examples of applications using DV methods, none relevant to the present context.

Sherr, S. (1998). Applications for Electronic Displays: Technologies and Requirements. New York: John Wiley & Sons, Inc.

Most of the contents are not relevant for present purposes. The book contains mostly derived data that is repackaged for design engineers for display systems. However, there are useful summaries on pp.340-341 on display technology characteristics and display requirements for different applications.

Vernik, R. ***A Proposed Reference Model Framework for Applying Computer-Based Visualisation in C3I*****. NATO RTO IST-20/WS-002 Workshop "Visualisation of Massive Military Datasets", June 2000, Defence Research Establishment Valcartier, Quebec, Canada.**

This paper provides a broad conceptual approach to applying visualisation methods to the full range of C3I issues. Of specific interest are the sections on visualisation approaches and their effectiveness in a domain context. Specific effectiveness criteria are provided. The bulk of the paper deals with an example of an asset visualisation tool for the air defence ground environment. Note: the paper was reviewed as a Powerpoint printout and no accompanying, detailed text narrative was available.

Wilson, K. G. (1993). Synthetic Battlebridge: Information Visualization and User Interface Design Applications in a Large Virtual Reality Environment. Unpublished Master of Science in Computer Systems, Air Force Institute of Technology Air University.

In spite of the intriguing title, this thesis is mostly a discussion of technical aspects of software for building a training simulator for command decision making.

Wojszynski, T. G. (1992). ***Scientific Visualization of Volumetric Radar Cross Section Data.*** **Unpublished Master of Science in Electrical Engineering, Air Force Institute of Technology Air University.**

This thesis is mostly oriented towards the development of algorithms for visualising radar cross sectional data. *Some of the techniques for applying colour, lighting and orientation may be transferable to some sonar applications.*

Wright W. (2000) ***Visualisation for Sonar Tactic Decision Aids.*** **NATO RTO IST-20/WS-002 Workshop "Visualisation of Massive Military Datasets", June 2000, Defence Research Establishment Valcartier, Quebec, Canada.**

This paper explores some useful concepts to enhance the visualisation of environmental data to assist the more rapid assessment of the underwater situation and to aid tactical decision making at the ASW command level. Concrete examples of new display formats to portray selected aspects of the underwater environment, including a 3d environment view, and 2d windows showing range, planning and analysed acoustic volume views. The paper represents work in progress rather than a definitive overview of the issues. Note: the paper was reviewed as a Powerpoint printout and no accompanying, detailed text narrative was available.

2.9 Summary and conclusions

The search failed to produce a large number of recent references that were strictly pertinent to the design of sonar combat systems, as might have been expected. The document that probably comes closest to providing the most comprehensive source of information that will be useful to system developers is **Handbook 5 - Guidelines for Maritime Information Management**. However, this provides a high level analysis of requirements and does not provide details of what specific forms of OMI will be required. More detailed recommendations on OMI issues relevant to sonar combat systems can be found in the report **Combat Information Center Human-Computer Interface Design Studies.**

It was hoped to find more papers on design guidelines for data visualisation, for data fusion and generic data management and possibly for sonar data displays specifically. However, this was not the case. While there continues to be research into optimising the display of processed sonar data and the way sonar operators analyse such data, the search revealed that little had been published, until fairly recently, concerning the design and use of automated aids to sonar detection. It should be remembered that initially the search was focussed on sonar combat systems and data visualisation in the hope that this would uncover all of the relevant material.

Somewhat late in the search process, it was learned that the TIAPS functionality employed a tactical overview display on which processed sonar data could be presented. The subsequent search for reference literature on tactical displays revealed a number of relevant original research reports as well as guidelines that will be of direct relevance to system design and heuristic evaluation of prototypes. Examples of these reports are: Undersea Warfare Sonar Systems Control and Display Standards and Conventions (1998,), Manning and Lankester (1999), Mulhearn,, Encarnaceo,, and Shane (1999), Osga, (1995) and Osga and Keating, (1994).

The preliminary function analysis of the TIAPS (see section 4.6.2 and following) system revealed a number of OMI issues that had not been anticipated at the start of literature search and review process. These included: operator interaction with automated systems, how operators work with environment and propagation models and how the role of the sonar operators may evolve from the roles of primary target classification and localisation to managers and interpreters of the output of automated aids in these areas. The search produced only one sonar relevant reference in this area and this paper underlined some fundamental issues in working with automated aids. Whether or not there is an established or emerging literature in the sonar domain in the above areas remains to be seen, however there may be some value in extending a future literature review to examine how these issues have been approached in other domains. In particular, the nuclear industry may be a useful source of material concerning operator interaction with (and trust in) automated systems, decision support systems for complex data management and possibly data fusion.

The general literature that was found through keyword search in the field of data visualisation was for the most part disappointingly inappropriate for present purposes. It comprised largely of demonstrations of data visualisation across a variety of applications with particular emphasis on the technical of presenting data (e.g. algorithms, software methods). Some of these demonstrations revealed potentially useful approaches that might be adapted for sonar systems. Few papers dealt with HF issues for data visualisation. Typically, those that did presented the material at a somewhat shallow level, garnishing known recommendations from standard OMI guidelines with little original research in evidence. A few reports identified some generic user goals for data visualisation.

The most promising source of literature on data visualisation for military contexts was found at the NATO RSG Data Visualisation website. This source provides links to ongoing NATO study group reports as well as to recent conferences specifically directed at visualisation of military data. The overall NATO RSG report provides an excellent framework for an analysis of visualisation issues and will be of value to system designers who wish to gain a better understanding of how human factors issues need to be considered in the design of systems with enhanced data visualisation capabilities. The taxonomies of human data usage, of types of data and the mapping of these two concepts provide a good starting point for system designers to frame basic questions about how to implement visualisation for any specific design context. It is highly recommended that system designers consult this reference source before considering the specific ways in which they expect to implement visualisation.

The recent annual conferences on data visualisation in military contexts provide both useful examples of conceptual analyses of military C2 information needs as well ongoing specific examples of implementations of visualisation approaches to military contexts. Of particular interest is the paper of Wright (2000) that provides concrete examples of underwater data modelling and visualisation of the sonar tactical environment.

In conclusion, a limited number of references were found that will assist either system designers in developing the OMI, or provide a basis for a heuristic HF review of emerging TIAPS prototypes. Most of these references pertain to the design of symbology and overlays for maritime tactical displays. Limited specific HF guidelines were found for data visualisation or data fusion that were relevant (or could be adapted) to sonar systems.

In view of the enhanced role to be played by automatic detection and tracking processes in TIAPS, it is recommended that an additional limited literature search be conducted to review potentially relevant material concerning operator interaction with automated systems. Issues to be explored include operator trust, setting and interpreting parameters for automated algorithms and possibly automated decision support in military combat systems.

3. Extension of the existing function analysis of CANTASS

3.1 Introduction

This section of the report fulfils SOW item 4 by providing an extension to the YARD functional analysis based upon the current operational usage of CANTASS. The revised function flow diagrams and descriptions for new functions are shown in Annex B.

3.2 Limitations

The information provided is based upon interviews with three instructors experienced in CANTASS and observations of the training simulator made during a one-day visit to the Underwater Warfare School in Halifax. The information pertains only to the functions performed by the Sonar Control Supervisor (SCS) and sonar operators in the conduct of passive sonar operations. As such, it excludes the following:

- functions associated with active sonar
- target motion analysis
- tactical correlation and integration of sonar information at the level of the Anti-Submarine Warfare Commander (ASWC)
- all system administration and maintenance functions.

3.2.1 Suggested modifications to YARD function analysis

The overall context of the YARD analysis is a "generic anti-submarine warfare (ASW) mission" i.e. monitoring, identification, and tracking sub-surface targets of interest, but not engagement. Engagement would normally be conducted by another asset (helo, Maritime Patrol Aircraft (MPA), or ship without CANTASS streamed). Information gathered during the visit suggests that there are two new types of goals/tasks that do not fit exactly within this broad definition. Also we have learned from our previous cognitive task analysis (Matthews, Webb and Bryant,1999)of the Operations Room Officer (ORO) position that missions in collaboration with other authorities may be on the increase. These may include finding, identifying and tracking surface contacts such as fishing vessels or illegal immigrant vessels, drug interdiction. The two new tasks are:

> Identification and tracking of *surface* vessels. The most common situations where this occurs are when a no emissions rule is in force, or where surface radar is down. The objective is to identify and track any friendly, neutral or hostile contact normally tracked by shipboard or other radar systems.
>
> Detection and tracking of a torpedo (enemy or friendly). One operator would have primary responsibility for this function.

As far as can be determined at this point, neither of the above requires unique new lower level functions to be added to the function analysis. Instead, for these two tasks there are differences in the way some of the generic variables identified in the YARD analysis influence sub-functions. For example, in the detection and tracking of a torpedo launch, distances may be much shorter than the typical range over which passive operations are conducted. As a consequence time frames are reduced and analysis and decision making is done under considerable time pressure.

At the time of the YARD analysis the context of typical missions was deep water. It now appears that **littoral** operations within a Task Group (TG) are becoming increasingly common. While this contextual difference does not change the major mission functions, it does have implications for increased operator workload due to more rapid oceanographic and environmental changes, more traffic and more manoeuvring by own ship. Sonar Operators are not well trained for this operational context now. Also the relative probability of certain mission functions may have changed. For example, it may now be more likely that surface vessels will have to be found and tracked close inshore.

A summary of critical points, comments and possible modifications to the YARD analysis is shown in Table 1 below.

3.2.2 Changes to the YARD analysis

Note that the initial number in each paragraph is the function reference.

1.1.1b Receive intelligence information

In setting up the array, operators not only use environmental information but also intelligence information. This function in the YARD analysis appears *as 1.3.4 Use intelligence information* only in the context of search for threat tonals. It is suggested that this function be added to the function flow, prior to setting up the array and the wording changed to "Receive and use intelligence information ". Since this is the first time this function appears in the information flow, it should be renumbered 1.1.2 and subsequent function renumbered in sequence. However, for convenience, and to avoid disrupting the existing numbering, it has been labelled 1.1.1b (and 1.1.1 relabelled as 1.1.1a).

2.0 Classification and Localisation

These two functions are combined in the YARD analysis on the grounds that they are difficult to differentiate in terms of the unique time phases when each is being separately performed. In the YARD analysis while there is some decomposition of the classification function into sub-functions, the only sub-function related to localisation is *2.1 Resolve Bearing Ambiguity*. Since another sub-functions relating solely to the localisation process has been identified, it is suggested localisation be treated as a separate function from classification. Further, it is possible that new tools available through TIAPS will differentially support either classification or localisation functions.

Therefore it is suggested to modify the analysis to include:

1.4 Localise target

1.4.1 Resolve bearing ambiguity (was 2.2.1) - including 4th level functions

1.4.2 Generate area of probability for target

Function flows associated with the above are shown in Annex B.

3.2.3 Additional functions

The following suggestions to add three additional functions are based on information acquired during the familiarisation visit. The degree to which the identified second level functions and associated third level functions are involved in these new functions, and the extent to which they may differ in operation from the existing functions, remains to be fully validated by subject matter experts (SMEs).

The three additional functions, and associated numbers, are:

- *Detect torpedo launch (3.2)*
- *Build surface picture (4.0)*
- *Prepare Oceanographic brief for CO (5.0)*

Detect torpedo launch (3.2)

This function may only be required to be performed during an engagement. The process likely involves functions: 1.3, 2.1, 2.2, 2.3, 2.4. 2.5, 2.6, 2.7.

The critical issues for operator performance are:

- the signature is difficult to localise – it appears only in broad band
- operators have to rely on contextual information
- information rates are very high
- few operators have had opportunity to witness a live signature
- once detected, the critical first task is to resolve ambiguity; this is usually through a best guess based on intelligence, since the signal information itself is not usually useful in providing cues.

Build surface picture (4.0)

This function is performed when surface radar is down or when other circumstances require that the surface tactical picture be compiled from sonar data.

This tasking appears to involve functions: 1.2, 1.1.1b, 2.1, 2.2, 2.3, 2.4, 2.6 and is done by operators. The general goal is to build the gross picture (note: target motion analysis (TMA) would be required to develop a more refined picture) and to provide identification of a surface group. To assist this task, the general tactical picture is available to operators and is displayed on a monitor between the two CANTASS consoles

A critical aspect of this task is that operators are less well trained in recognition of surface vessels and also the database of known signatures is less complete.

Prepare Oceanographic brief for Commanding Officer (CO) (5.0)

This is done once a day (with a 24 hour overview).

3.2.4 Summary of critical points and comments

Table 3: summary of critical points, comments and possible modifications to the YARD analysis.

Function	Modification (bold) or Comments
1. Search and Detection	
1.1 set up array	ASWC and Towed array supervisor (TasSup decide where to place array. – takes 2-5 mins to setup and reset verniers Vernier setup based upon Intel and experience.
1.1.1 Receive environmental information	This task is repeated throughout the mission as new information comes in about every 30 minutes. **1.1.1a Receive and use intelligence information**
1.1.2 Advise on scope and depth of array	
1.1.3 Set array receiver parameters	
1.1.4 Set signal processing parameters	Set up main windows; integration period is usually set to 8-32 seconds.
1.1.5 Set track processing parameters	This involves setting minimum probability of detection for Automated Initiated Tracks (AIT). Note operators tend to turn the AIT function off, because the system is continuously failing and initiating new tracks, in many cases for the same source. This generates too much "noise"
1.1.6 Set system parameters	Parameters such as: magnetic variation, heading, source (operator or array), array depth, water temperature obtained from stateboard.
1.2 Isolate non-threat tonals	Generically referred to as "sanitising the array"
1.2.1 Obtain information on known non-threats	This is essentially eliminating the "noise" from TG using SB and 3B mode. This is a major task in a seven ship TG and is done repeatedly on most missions, as frequently as every 15 minutes. In littoral settings more difficult, more contacts, and more noise. The process may also increase display noise since identified target tracks cannot normally be dropped under existing operational procedures.
1.2.2 Isolate own force tonals	

1.2.3 Obtain information on own force manoeuvres	Done in parallel with 1.2.4, manoeuvres range from simple changes of course, avoidance, helo operations, zig-zag, etc.
1.2.4 Isolate other non-threat tonals	High workload. Considerable manual data logging. Task shared by Sonar Operator (SonOp) and SCS.
1.3 Search for threat tonals	Frequently done in parallel with 1.2 by one SonOp. Typically one SonOp searches forward, the other aft. Initial search based on Intel, hunches based upon experience, May be done in response to requests for info to correlate with sensors on other platforms. Done in 3B mode and takes 4-5 minutes. *An on-line database of known signatures would facilitate this task.*
1.3.1 Process raw acoustic data	Critical task sequence is: target detection and identification, classification, speed, bearing, bearing accuracy/uncertainty No specific tools available to assist ID.
1.3.2 Check acoustic displays of processed data	
1.3.3 Examine threat tonal list	CFC 113 – provides a "cheat sheet" of acoustic signatures in document format. Mostly tabular data, but has some grams. Also have available from training packages real acoustic data from known sources
1.3.4 Use intelligence information	Ops build up local database during course of operation. Another source is a CD from the Acoustic Data Analysis Centre (ADAC).
2. Classification and localisation	Once a possible contact is detected, one SonOp will continue the search fore and aft), while the other looks after contact identification and tracking. **Suggest separate classification from localisation functions,**
2.1 Maintain detection	
2.1.1 Diagnose why contact has been lost/faded	

2.1.2 Change signal processing and array receiver parameters	
2.1.3 Advise on change of course, speed of ship, scope and depth of array	
2.2 Resolve bearing ambiguity	Done by SonOp may take 5-20 mins.
2.2.1 Check broadband display for true bearing clues	**2.2.X Determine area of probability for localising target** (to be added as a sub-function under "localisation") This usually through a cross check with another platform Range estimate depends on CZ, BB, DP and speed across beams
2.2.2 Communicate with ops room during manoeuvre	
2.2.3 Commence updating TMA with bearing frequency and time information	Not done at level of SCS or SonOps
2.2.4 Update target detail	
2.3 Provide initial classification	
2.4 Maintain target details	
2.4.1 update markers and tracks	
2.4.2 update target details	A single operator will normally track one identified targets at a time, rarely two. If tracks are lost, contact details are deleted. System can maintain 99 contacts Tracks are dropped if they are deemed not to be a contact of interest (note this track tag only not the signature lines). Deleted tracks are automatically dropped as update to CCS .
2.4.3 update ADLIPS	Replace ADLIPS with Command Control System (CCS). (ADLIPS was a predecessor system to the CCS)
2.4.4 initiate and delete tracks	
2.4.5 co-ordinate BB information	

2.5 separate threat target from own force tonals	Needs to be done as info fades in and out. SonOp does the analysis.
2.5.1 Communicate need to separate signatures	
2.5.2 re-evaluate signature in beam(s)	
2.6 data logging	This task is intensive and critical.
2.7 refine classification	Types: operator or command classification (ASWC-ORO-CO). ASWC responsible for getting cross reference info and feeding down to SCS and Ops.
2.8 Provide information for TMA	CANTASS v4 has tools for Target Motion Analysis (TMA). Currently done verbal comm link (not data) Investigate area of operation (AOP) MPA and Helo do own target ID – provide info via ASWC to ORO. Picture compilation is done at the level of the ASWC. Towed array sonar reports (TASREPS) are updated every 15 mins or more frequently for important new info.- this may be through stateboard, but usually verbal. Have ability to recall acoustic data – this could be used to assist the review of critical data. Contact report goes out to other ships via SCS-ASWC on external nets. Will look for dynamic changes during an engagement and may provide some damage estimates
2.8.1 create ADLIPS	Now done automatically through CCS
2.8.2 communicate with TMA to synchronise timing	
2.9 provide information for MPA/HELO ops	

3.0 Prosecute target **3.2 Detect torpedo launch**	the signature is difficult to localise – it appears only in broad band - operators have to rely on contextual information - information rates are very high - few SonOps have had opportunity to witness a live signature - once detected, the critical first task is to resolve ambiguity; this is usually through a best guess based on intelligence, since the signal information itself is not usually useful in providing cues.
4.0 Build surface picture	
5.0 Prepare oceanographic brief for CO	This is done once a day (with 24 hour overview)

3.2.5 Ancillary functions for which future analysis may be required

The following functions were briefly mentioned during the familiarisation visit, it is not known at the present time, whether analysis of these will fall within the scope of the present project objectives.

- Bathy drop
- Sonarbuoy deployment
- TMA

3.3 Summary

Overall, the YARD analysis remains substantially accurate and complete in reflecting the functions involved in the current operational usage of CANTASS. A small number of changes and modifications are suggested to reflect current practice and these are integrated into the revised function flow in Annex B2.

4. TIAPS Function Analysis

4.1 Background

The TIAPS system is a research and development technology demonstrator to explore the feasibility of combining passive and active sonar systems with a view to improving underwater picture compilation. In addition, certain tools and capabilities are being explored with a view to reducing the operator workload involved in the existing search, detection, identification and localisation tasks. At the present time it is not known what aspects of the system may be eventually placed in an operational environment.

A full description of the TIAPS system can be found in CDC (1999a,b).

4.2 Objectives

- To provide a base reference framework for existing TIAPS functions under development that will also allow future functions to be integrated
- To identify critical operator tasks that will require some research effort to provide appropriate human factors (HF) input to the design process.
- To identify areas of functionality where the design of the operator machine interface (OMI) will need to be sensitive to specific operator requirement or limitations.
- To identify areas of the TIAPS OMI that will require particular research and development effort.

4.3 Mission Analysis

While the SOW does not specifically require a mission analysis to be conducted as the normal preliminary step to a function analysis, it is important to view the TIAPS functionality against possible mission contexts. Without such a context, any description of the system functions could be inaccurate and inappropriate. Thus, some speculation is in order concerning the potential operational roles for TIAPS. This process should be regarded as somewhat conjectural right now, since the potential applications for TIAPS will no doubt change as a result of two factors. First, at a technical level the functionality will continue to evolve, as experience is obtained on how functions actually work in practice (e.g. autotrackers) and, second, at a military level new strategic directions, doctrines and mission roles may emerge.

Information on the possible roles for TIAPS can be ascertained from the scientists centrally responsible for its conception and development, the engineers responsible for its implementation and the military. The information presented below therefore represents the outcome of some discussions with defence scientists, software developers and information gathered from relevant system technical documents as well as military concept documents representing emerging directions and doctrine.

TIAPS is clearly designed to address the Navy's continuing requirement for surveillance operations. This requirement is one of the major areas for future force planning and defence thrusts (National Defence: VCDS Force Planning Scenarios, 1999) as well a focus for future naval R&D activities (The Naval C2 Blueprint, 2010). The surveillance process will continue to involve the acoustic detection of both surface vessels and submarines. Against this general requirement there are two important factors to consider. First, the detection range of existing active sonar systems is challenged by modern, quieter submarines. Second, there is an increasing trend to move from blue water operations to Littoral environments. (Theriault, 1999)

In addition, at an operational level there is a desire to improve the Common Operational Picture (COP) across levels of command as well as improving the ability to make rapid and accurate command decisions under increasingly higher levels of information load (Handbook 5, 1997). As a result, from a mission perspective there is both a need to integrate the information provided by TIAPS upwards into the COP, as well as providing information concerning the current tactical picture (TP) downwards to underwater warfare (UW) activities.

A further factor in considering TIAPS in an operational role is that there will be a future need, as part of general sonar information management, to integrate data from other sources such as multi-statics into a common sonar suite.

4.4 Function Analysis

Function analysis is described as analysing a system in terms of the functions that must be performed and defining the logical units of behaviour of the system (NATO RSG 14,1992). However, this presumes that the system or mission goals have been defined to allow a specification of such required functional components. In the case of TIAPS which is an R&D product there is some uncertainty concerning the specific system goals, which will probably not be finally resolved until the product has undergone sea trials and has been integrated into naval operations. Feedback from what is operationally appropriate and feasible with the system will then provide at some point in the future the ability to refine the theoretical and design system objectives.

A further consideration with respect to function analysis is the perspectives that may be brought to examining and describing the system of interest. The operational perspective requires an analysis that looks at the system in terms of what mission goals it is designed to achieve, and defines the necessary functions that comprise the process. In contrast, from the systems engineering perspective, the word "function" is often used by software engineers to describe some attribute of a system at the coding level. For example, tools that are used to assist the sonar operator in the analysis of sonar lines of interest may be thought of as defined functional elements of the software. The existing documentation on TIAPS (CDC 1999), provides a good example of functional descriptions of the system components from such an engineering perspective. For present purposes, the view has been adopted to examine the system in terms of its potential role in an operational environment; thus, the system software functions described in the above documentation have been integrated, where possible and appropriate, into this perspective.

While function analysis may follow a variety of approaches, the SOW requires a product that follows the format adopted in the YARD (1989) analysis of CANTASS, namely a function flow diagram. This approach shows the sequential arrangement of functions as well as functions performed in parallel. (Note: the typical use of the term *parallel* in a function analysis does not imply anything about the operator having to actually perform tasks in parallel. Instead, it represents a group of functions whose completion or output is required before a subsequent function).

A typical function analysis represents a progressive decomposition of the system downwards to the point where individual operator tasks are able to be defined. For present purposes, it was agreed with the technical authority that the decomposition would be conducted no lower than third level functions, where such decomposition was possible. It was hoped that this would be a sufficient depth of analysis to allow the identification of gross and critical tasks that would be central to the achievement of functions.

4.5 Process

The normal process of using a scenario-based approach to define system or mission goals is infeasible given that the TIAPS system is a research and development concept under evolution, rather than a system that is being built to meet specific operational criteria. While potential mission environments have been identified, and these can guide the process of function analysis to some extent, in practice the system can only be analysed in terms of potential capabilities in generic UW operations. Operational elements such as surveillance, detection of contacts, tracking contacts, prosecution, and building both the recognised maritime picture (RMP) and common operational picture (COP) will no doubt continue to be cornerstones of future UW operations.

The actual process adopted for describing the functional elements of TIAPS was therefore somewhat pragmatic and informal. Background documentation was read, discussions were held with subject matter experts (SMEs) provisional decompositions and analyses were generated and subsequently refined as a result of feedback and further discussions.

The original intent was to decompose functions down to the second or third level, where appropriate, to be consistent with the prior function analysis for CANTASS (YARD, 1989). However, it was decided to go lower levels of decomposition for some of the more critical areas of TIAPS, in order to understand better some of the operator tasks, their relationship to each other and to provide a map of the overall complexity that results when both active and sonar systems are combined into a common suite.

4.6 Results

The results are outlined in three major sub-sections; the first deals with the TIAPS mission goals and concept of operations, the second covers the function analysis and the third, critical tasks.

4.6.1 Mission goals and concept of operations

The generic mission goal that TIAPS is designed to serve can be described as

"Create and maintain the UW tactical picture"

This picture comprises elements of:

- Surface vessels and sub-surface vessels
- All detected sonar sources
- Contact tracks
- Location and movement of contacts of interest
- Selected geographical and underwater environment information

Unlike CANTASS, where the role is primarily one of surveillance of relatively "noisy" contacts in deep water, TIAPS missions are likely to involve additional types of operating environments, which include:

- shallow and/or littoral waters with associated impact on performance on acoustic sensors
- tactical scenarios in which there is a "proactive" search for a specific contact (i.e. not generic surveillance as is the case with CANTASS. However, there is no consensus among the development team on this point and military SMEs have yet to comment on this role)
- quieter submarines which will be more difficult to detect by passive sonar, particularly in a littoral environment
- detection of torpedoes
- undersea launch of anti-ship missiles
- convoy barrier operations

The role of active and passive

TIAPS will provide access to both active and passive processed acoustical data. The TIAPS system can operate in one of three modes: passive only, mainly passive + occasional ping and regular active schedule. The decision is made at the task group (TG) level on which mode is used and is based on the tactical situation and ongoing emissions policy. One role for the active component of TIAPS may be for target localisation, while passive data could still be required for identification and classification. Active sonar may also play a greater role in shallow water and littoral contexts.

The role of operators

The role of the operator may change from the present focus on the primary task of the search for threat tonals (and associated tasks) to one in which the first level function is to respond to "alerts" (i.e. the output of automatic processors for detection). This may be accompanied by a shift in resources from the present compliment of a sonar supervisor and two operators, to a two-person operation with just one operator and supervisor. It is speculated that the supervisor's role will be to ensure that the UW tactical picture (based upon analysed data from automated processes) is accurate and current. To achieve this the supervisor may need to conduct additional analyses using system tools on either active, passive data or both.

Operator aiding

The provision of a tool suite to assist the operator perform a variety of operational tasks is anticipated. This suite may include display parameter tools (e.g. contact rings, environmental overlays, integrated data, tools to assist in the selection of models, such as bathymetric and ping sequences)

System overview

Hardware: current thinking is that the system will have two high resolution colour monitors. At present, development work is proceeding with a Sony 2kx2k resolution CRT monitor, but it is envisaged that final configuration will comprise two 21" 1600x1200 LCD, display panels with 4:3 aspect ratio. These will be arranged either in an over-and-under configuration, or tiled contiguously along the horizontal dimension (to provide a 'virtual' monitor. There is consideration of a plan to use a touch panel as the primary input mode, supplemented by as trackball and keyboard for minor input.

TIAPS is capable of generating acoustic data on over 200 beams. Since it would be impractical for operators to perform the fundamental function of signal detection by scrolling through the beams (as is the case at present), computer assisted detection provides a core functionality in the system.

Therefore, a major change in operator roles from CANTASS is anticipated, in that a primary task for the operator will be to monitor the outcome of automated processes that he/she has configured and initiated. The primary task of the supervisor will be to determine the ground truth, or what is believed to be "real", based upon further analysis of the information provided by automated processes. The supervisor will have the responsibility of ensuring that the underwater tactical picture is accurate so that it can be incorporated into the common operational picture at the command level.

The primary TIAPS display comprises a tactical situation map (derived from the Global Command and Control System (GCCS) library, as well as standard commercial oceanographic and geographical databases); Link 11 data, multistatic sources and the RMP can be overlaid on this.

Known surface and sub-surface contacts are displayed using standard NATO symbology for contact type and course. Operators can click on a contact for more detailed information. Such contacts may include friendly, enemy and neutral vessels and commercial traffic.

Unknown contacts are depicted as coloured coded dots- red = fast closing, green = slow closing, yellow = fast leaving. For each unknown contact, the operator can invoke a *contact ring* located concentrically on the current own ship's position. Textual data located on a computed bearing on the ring perimeter show the relevant broad or narrow band frequency information for the target. The ring diameter itself bears no spatial relationship to the target, but serves as a convenient parking place on which contact information can be readily located. Unknown contacts can be interrogated (via a mouse click) to access processed passive data, and hence make available all of the existing functionality of CANTASS. Additional tools such as ratio cursors are available to assist the classification process.

Several tools to assist the operator are currently under development. The following represents some examples that have been demonstrated to date during the familiarisation for this contract and is not intended as a complete listing of the tool set.

Contact association: this tool is designed to allow an operator to associate data in one window with that in another, for example between the tactical display and a broad band display.[3] For example, on the tactical display the operator may sweep a radial cursor centred on the ship and locate a track or contact of interest, in an associated broad band display, this movement is tracked and shown as moving vertical cursors across beams. In this way, acoustic data can be simultaneously associated with processed contact data and the operator may be able to resolve contact details or determine more about the contact identity.

Target motion analysis: This tool will integrate and refine some of the existing tools (e.g. Passive Localisation Assistant -PLA) to provide a more rapid and accurate method for assessing the track and speed of a contact of interest. The display shows the Ecklund legs of a ship's track with associated bearing sectors on which contact data has been detected. The operator can specify a possible target track within this area of contact by plotting a line and obtain immediate feedback of the residual data fit around the line. In this way, the operator can manipulate contact characteristics in real time and receive visual feedback on the track that best fits the data.

4.6.2 Function analysis

The following section summarises the TIAPS functions that have been identified. Function descriptions typically comprise the following components (derived from the YARD analysis): function descriptions and function flow diagrams, full details of which are provided in Annex C.

Function descriptions have the following format (based upon the YARD documentation).

1. Name of Function
2. Missions Under Which Function Occurs
3. System Units Which Support Function
4. Superordinate Functions
5. Sequential Categorisation of Functions
6. Estimate of Criticality of Function
7. Critical Variables (e.g. own ship speed, own ship manoeuvres, oceanographic conditions)
8. Required Quality of Output for Function

[3] The word "window" is used to represent a separate display entity that shows data containing some aspect of the system functionality, examples would be a broad band display, tactical display, beam display etc. The word display is not meant to imply that there is a unique monitor associated with each display format. In other words, many display windows are capable of being rendered on each of the monitors that will comprise the TIAPS workstation.

9. Estimate of Probability of Failure to Complete A Function
10. Consequences of Failure to Complete A Function
11. Estimate of Time to Completion
12. Sub-functions Or Tasks
13. Sequencing of Sub-functions or Tasks
14. Allocation of Function to Man, Software or Hardware
15. Interdependency Of Functions

Given the early stages of development of the TIAPS system, it is not possible to address with a reasonable degree of certainty the data that should be entered into many of these descriptions, for example, probability of failure and time to complete functions. Further, based on the YARD report, the category *Critical Variables* tend to be somewhat constant across most functions (even if they could be identified at this stage). Therefore, the function descriptions for each function will typically only include items1, 4, 5, 6, 10, 12, 13, 14, 15. The remaining categories will remain as placeholders for now to allow more detail to be incorporated into the functional analysis as the system evolves.

An additional category "Comments" has been added to allow the entry of specific issues of importance that will need to be considered in the future.

The function of "building and maintaining the RMP" has not been included in the analysis, although it seems clear that TIAPS could provide many of the underlying tools that are necessary. Building the RMP is a somewhat different function, although related to the core TIAPS function of building and maintaining the UW tactical picture. For the RMP, all contacts and relevant data within the area of interest must be plotted and identified, to whatever degree is possible. The RMP forms a contextual backdrop for the conduct of ongoing operations and for the planning of future actions. The tactical picture may be regarded as a local subset of information within the RMP in which information and data of immediate relevance to tactical decision making is plotted. Thus, for any particular operational decision, information may needed to be added or filtered from the RMP. Information to be added might include estimates of threat ranges, points of closest contact and extrapolations of future positions of contacts of interest. Information removed might include anything that is not relevant to the specific tactical decision and which clutters the screen. The decision as to whether include building the RMP into the functional analysis for TIAPS may best be postponed until further functionality is developed and the role of TIAPS has been analysed in terms of how it will serve the UW team and how that team might be constructed in future. If fewer personnel are anticipated then functions such as building the RMP may well fall within the responsibilities of the TIAPS team; certainly, TIAPS will have the generic capability of supporting this role.

1. **ANALYSE MISSION**
    - 1.1. Receive Information
        - 1.1.1. Receive environmental information
        - 1.1.2. Receive information on mission
        - 1.1.3. Receive organic and non-organic intelligence
        - 1.1.4. Receive direction on threats from command team
    - 1.2. Configure workstation
        - 1.2.1. Configure workstation for mission type (load appropriate databases)
        - 1.2.2. Set local preferences
    - 1 3. Configure active sonar
        - 1.3.1. Set waveform
        - 1.3.2. Set wavetrain
        - 1 3 3. Set ping bundle
        - 1.3.4. Set false alarm rate for autodetectors
    - 1.4. Configure passive sonar
        - 1.4.1. Set false alarm rate for autodetectors
    - 1.5. Set up required operating mode (fully passive, mostly passive-infrequent pings, regular active schedule)
2. **CONFIGURE SYSTEM MODEL**
    - 2.1 Create and maintain environmental model (continuous process)
        - 2.1.1. Add current information (sound speed profile, location, sea state)
        - 2.1.2. Run and refine model (based largely on operator experience)
    - 2.2. Create and maintain sonar model
        - 2.2 1. Update threat information
        - 2.2 2. Update environment information
        - 2.2.3. Run model
        - 2.2.4. Array motion
    - 2.3. Evaluate Model
    - 2.4. Communicate values for sonar analysis
3. **ASSESS SYSTEM**
    - 3.1. Assess environment
    - 3.2. Assess Sonar
        - 3.2.1. Analyse array motion

4. **CREATE AND MANAGE TACTICAL PICTURE**

- 4.1. Receive mission parameters
- 4.2. Manage TP overlays
- 4.3. Select and manage DII/COE data
- 4.4. Manage contacts
  - 4.4.1. Reduce contact clutter
  - 4.4.2. Identify non-threat contacts (possibly of auto process on passive side)
  - 4.4.3. Identify and respond to unknown contacts
  - 4.4.4. Determine contact priority
  - 4.4.5. Determine contact correlation/association (same or different source)
- 4.5. Analyse contact
  - 4.5.1. Analyse passive sonar data
    - 4.5.1.1. Configure system
    - 4.5.1.2. Search for contacts (detect)
      - 4.5.1.2.1. Configure signal followers
      - 4.5.1.2.2. Check what computer has merged
      - 4.5.1.2.3. Check what auto process has missed
      - 4.5.1.2.4. Verify contacts that are auto-detected
      - 4.5.1.2.5. Select sonar display configuration mode (e.g. bb/demo)
      - 4.5.1.2.6. Initiate signal followers for weaker signals not auto-detected
      - 4.5.1.2.7. Analyse acoustic data
      - 4.5.1.2.8. Analyse non-acoustic data
    - 4.5.1.3. Classify
    - 4.5.1.4. Localise
      - 4.5.1.4.1. Manage TMA processor
        - 4.5.1.4.1.1. Generate localisation solution
        - 4.5.1.4.1.2. Evaluate localisation solution
  - 4.5.2. Analyse active sonar data
    - 4.5.2.1. Check bathy information
    - 4.5.2.2. Configure transmission
      - 4.5.2.2.1. Set Ping sequence
      - 4.5.2.2.2. Set Waveform
      - 4.5.2.2.3. Set sector
    - 4.5.2.3. Configure receiver
      - 4.5.2.3.1. Configure CW
      - 4.5.2.3.2. Configure FM

4.5.2.3.3. Configure ER
4.5.2.4. Monitor performance/progress of ping schedule
4.5.2.4.1. Adjust or change model as required
4.5.2.5. Search for contacts
4.5.2.6. Analyse data
4.5.2.7. Classify contact
4.5.2.7.1. Extract features
4.5.2.7.2. Reduce clutter
4.5.2.7.3. Analyse non-acoustic data
4.5.2.8. Localise contact
4.5.2.8.1. Determine latitude and longitude
4.5.2.8 2. Determine course/speed

4.6. Manage Tracks
4.6.1. Maintain track positions
4.6.2. Correlation/associate tracks
4.6.3. Maintain track database
4.6.4. Report tracks

4 7. Analyse tactical picture
4.7.1. Determine contact threat level
4.7.2. Ensure all tracks accounted for
4.7.3. Delete contacts as required

4.8. Refine configuration of automated processes
4.8.1. Evaluate performance of automated processes
4.8.2. Adjust parameters

5. RECORD AND ANALYSE DATA

4.6.3 Critical Tasks

At the present level of system development some degree of speculation is required in order to establish critical tasks that will need to be performed. The identification of critical tasks will be an ongoing process, first, as parts of the system become functional and available for operators to work with in a demonstration mode, and, subsequently as the entire system is fielded and operational experience gained. At present, the specification of core and critical tasks is based upon some broad conceptions of how the system will be operated and how it is similar or different from current operational practices in either the active or passive sonar domains.

As a first step we can consider the critical tasks involved in passive sonar analysis and see how they may be different in TIAPS. We can also examine tasks that will be anticipated in TIAPS but have no counterpart in CANTASS.

The primary tasks in passive sonar analysis (based on CANTASS) are:

- isolation of known tonals
- search for threat tonals
- detection of tonals
- contact identification
- contact localisation and tracking
- contact classification

Provisional new tasks in TIAPS are:

- configuring the system
- evaluating the accuracy of the output of automated processes
- monitoring the output of automated processes
- analysing the "truth" concerning auto-detected contacts
- refining automated processes
- building and monitoring the tactical picture
- building and maintaining the UW RMP

The first three tasks in the first list, which are highly operator intensive in CANTASS, may all fall within the capability of automated system functions in TIAPS. Given improvements in detection sensitivity of the system and an improved spatial resolution of beams, the amount of processed information available will be considerably higher than is currently the case in CANTASS. It would be unrealistic to expect that a single operator, using existing CANTASS procedures of sequentially scrolling through beams to find acoustic information of interest, could process the information in a sufficiently timely manner for operational purposes. TIAPS transforms this process through the implementation of automated signal detection and analysis. Hence, the operator's initial, critical task will be **to configure the system** to allow such automated processes to run appropriately for the specific circumstances of the mission context and the local environment.

It is also expected that the tasks of localisation and tracking will also be transformed under TIAPS. At present these tasks are performed off-line from CANTASS through largely manual processes, with some computer assisted tools for target motion analysis (TMA). These tasks are also normally performed by personnel other than the CANTASS operators. Under TIAPS, TMA will be fully integrated into the system, which will provide interactive tools for more rapidly estimating target course and speed.

The process of contact classification will essentially involve the same sub-tasks that are part of existing active or passive sonar analysis. In TIAPS, when operating in dual mode, operators will have additional information available to assist the classification process. While this may improve the accuracy of the process, it is not known at this time whether there will be additional analysis time required to integrate information from the active and passive systems. It is also possible that some of the tools that allow association between acoustic data and plotted tracks may assist the classification process.

TIAPS tasks

System configuration.

There are two parts to this process. The first step is an initial configuration of the workstation for the role of the operator or supervisor together with the setting of some broad operational parameters determined by the tactical context. This would include determining the relative roles of active and passive and configuring each system for the local water environment and other conditions affecting system transmitters and receivers. The second step in the process is the task of configuring automated detectors. This will require the operator to determine values for a number of parameters that will influence the performance of the detector. It is expected that this process will be facilitated through menu selection from a number of pre-configured parameter data sets in a database. It will be critical for the operator to perform this task with accuracy and in a timely manner. Hence, there will be a need to develop an appropriate OMI that facilitates this process. Since the specific sub-tasks involved in setting up the automated trackers have yet to be identified, the particular OMI requirements cannot be specified. One fundamental task that will be required is the determination of the appropriate criterion threshold for detection by evaluating the performance of automated processes.

Evaluating the performance of automated processes.

Since the system is not a perfect detector, and signals and noise come from overlapping acoustic distributions, a trade-off will always have to be made between making the system yield the minimum number of false alarms, while at the same time ensuring that potential targets are not missed. Since operators will have no a prior knowledge of how the local conditions may influence such a criterion, there will be an ongoing secondary critical task for operators to ensure that the detection criterion is optimised. The achievement of the required proficiency in performing this task will need to be a new focus for training of operators, but no matter the level of proficiency achieved, operators will need to be constantly evaluating the performance of automated detectors on an ongoing basis. To achieve this, there may be a need to develop a capability for operators to replay the recent acoustic data history and examine the effects on signal detection outcome (and false alarms) by manipulating the criterion setting in more or less real time. In this way operators would be able to readily determine what criterion would be most effective for the current operational conditions. Special consideration will be need to be given to developing an OMI that facilitates this task.

Monitoring the activity and output of automated processes

Unlike CANTASS, where the detection and track initiation processes are largely processes that are assigned to the operator, in TIAPS the operator's role is to monitor the output of such processes. As an example, one approach under consideration is to show contacts as small plots on the tactical display, coded according to their threat profile, using the coding scheme outlined earlier. Hence the operator's tasks will involve the detection of new contact plots on the screen, the determination of their priority for further scrutiny and the analysis of the underlying acoustic data to establish "truth" concerning the auto-detected contact.

Analysing the "truth" concerning auto-detected contacts

Given that there will always be some uncertainty concerning the meaning of the detected contact, a major task for the operator will be to analyse the auto-detected contact to the point where it can either be rejected as noise, or accepted as a contact of interest that will require further analysis in terms of identification, tracking and classification. As an initial step, the operator may use information on the contact ring to establish whether there is a known track along the bearing of the target and whether the contact may be associated with this known track. As an additional step it may be necessary for the operator (or supervisor) to analyse the underlying acoustic data that are associated with the contact. This process may be somewhat similar to existing methods of active and passive acoustic analysis, supplemented by new TIAPS tools. For example, the "association window" will allow the operator to associate graphically both processed acoustic data and sounds from a potential source with tracks displayed upon the tactical display.

Refining automated processes

As a result of the three prior tasks, the operator may come to the conclusion that automated detectors and processes are not providing the required information. Consequently, the operator may have to fine-tune the configuration parameters of these automated processes. In deep water operations and low traffic volumes, this task may need o be done somewhat infrequently. However, in littoral operations and higher traffic volumes, there may be a need for frequent adjustments of parameters. Hence, an OMI design that allows such adjustments in an expeditious and accurate manner will be required.

Building and monitoring the tactical picture (TP)

Whether this task is performed at the level of the TIAPS team or higher in command structure is unknown at present. Given that TIAPS will provide an overall TP display format, it is possible that the supervisor position may take on this responsibility. The goal of this process is to link the information provided by sonar analysis to the immediate operational context of the mission. In other words, sonar information needs to be interpreted in terms of its tactical significance. Given the potential downloading of information from the Defence Information Infrastructure Common Operating Environment (DII/COE), other databases, link data and other sources, the TIAPS supervisor will have the necessary functionality to create an intelligent tactical picture that may serve the needs of higher command levels. The task of building the tactical picture will involve sub-tasks of data filtering (to eliminate tactically irrelevant data), information integration and possibly projection of future state. Related to this process is the task of building and maintaining the UW RMP.

Building and maintaining the UW RMP

Again it is not known if this task would be performed by the TIAPS team, however the system provides the necessary functionality for the task to be performed effectively at this level. At present, the building of the UW RMP is essentially a manual and intensive process that involves the integration of passive and possibly active sonar information, data from sonabuoys, intelligence reports and link data. The goal is to identify and classify all UW information in the area of interest. The tools and functionality available in TIAPS will make this a process that is more effectively and expeditiously accomplished than with present approaches. TIAPS not only provides a comprehensive system for analysis, but also for data presentation within a tactical format that can be readily shared among the command team.

4.7 Heuristic Human Factors Review of the TIAPS OMI

The following discussion is based upon a review of two aspects of the display functionality, namely the overall tactical sonar display and a "contact association display". While, none of the underlying active or passive data displays have been available for review, it is understood that these have a similar format to the existing 510 and CANTASS systems. As such, it would be somewhat redundant and uninformative to review them in the present context. Since these functions represent work in progress rather than the ultimate design concept, it would be unwise at this stage to provide definitive comments on the full spectrum of TIAPS design issues or to emphasise too greatly any existing limitations in the concepts under development.

The potential range of human factors issues in TIAPS is quite broad, ranging from detailed issues of display design up to cognitive representations of complex tasks. The listing below does not represent an ordered set of priorities for improvements but can be thought of as an initial evaluation of the currently available functions, as well as some speculation concerning issues relating to the development of a variety of functions, in particular relating to the use of automated system features.

4.7.1 Display issues

4.7.1.1 Contact symbology: size and colour.

There is clearly a trade-off between the size of the symbology and its potential visibility. There is a need to keep contact symbology small because of the requirement to have minimal spatial uncertainty, to allow history trails to be displayed and to allow multiple, non-overlapping targets to be rendered. The use of a small, single pixel target to accomplish this raises the possibility (and until further investigation, this is just a possibility) of some human perceptual issues, as noted below.

4.7.1.2 Discriminability of coloured targets.

The choice of red colour code to indicate the high salience of fast closing targets is a natural one, however some potential problems can be identified. The red channel on most coloured CRT displays has limited energy output (compared with green) and hence the maximum luminance of a red target is relatively low. While the associated luminance output is sufficient under most circumstances to generate a stimulus that meets luminance contrast guidelines for detection, there are circumstances where the visibility of the contact symbols may become compromised. Such circumstances are:

- where the ambient room light is red and or at a low level
- LCD display technology (for which visibility of single pixel targets and reduced display contrast with off-axis viewing are known problems)
- the overall display contrast and/or brightness has been reduced by the operator (for example, to prevent other display elements from being too visually dominant)
- a cluster of adjacent symbols is in close proximity to each other
- where the contact symbol may be overlaid by, or be close to, other display elements (e.g. contact rings, numerical data)
- where the display luminance output has degraded over time, in which case luminance output for the red and blue channels becomes more compromised than green, because of the lower overall energy output.
- Where other display elements (for example, green or yellow symbols) have higher energy and hence greater luminance contrast. These may mean that they are easier to detect, are more visually prominent and hence have the potential for impairing the recognition of the red contact symbology.

Overall, it may be tentatively concluded that the high salience and alerting properties of the contact may become compromised by the above factors.

Some immediate design solutions to consider are:

- Consider other colour coding, symbology, or format options (e.g. flashing) for the high salient contacts. NATO STANAG 4420 may provide some guidance on symbology for contacts that have not been confirmed or formally classified.
- Use a larger symbol for the contacts
- Ensure that the operator is provided with a brightness control that allows the luminance of the contact dots to be adjusted independent of other display elements.
- Provide independent brightness controls for all major display elements (e.g. overlays, alphanumerical data blocks, contact rings, oceanographic and geographical data,)
- Provide for a blink capability to red contact symbols (under appropriate circumstances) to increase discriminability.

- Allow selective display elements to be turned off under operator control, where their close spatial presence may impact upon the discriminability of contact symbols

Some of these issues will need to be investigated empirically during system development. Of priority will be the need to look at the provision of independent brightness control to some display elements, since past experience with similar technologies and software suggest that COTS products have limited capability to provide such functionality.

4.7.1.3 Text and fonts

Since the tactical display format may result in the display of a large number of contacts and tracks and associated symbol and alphanumeric data, the potential exists for display clutter. Such clutter may result in impairments to the operator's ability to detect, search and read information. Hence, some discipline will be necessary in the choice of text and symbology to minimise this potential. The following areas will need to be addressed: selection of font type and size, contrast and colour characteristics, size and colour coding of symbols. The evaluation of these areas will need to be conducted within a variety of display formats ranging from a relatively uncluttered display (with minimal background fill and overlays) to ones which contain large amounts of data, overlays involving area fills and overlays with other types of information (e.g. contact rings).

4.7.2 Contact rings

The concept of contact rings, as described earlier, is to provide the operator on the tactical display with any contextual data that may be available on a particular bearing. The proposed manner of implementation using rings does however raise some human factors issues. The most important concern is that bearing rings will be confused with the highly overlearned concept of range rings; these are widely used in tactical displays in several domains to provide a visual cue of range distance information normally centred on own platform. In conditions of stress, high workload and rapid decision making, operators will tend to really heavily on overlearned concepts, thus a contact ring could be confused with a range distance ring. It is recommended that the design should be re-evaluated to eliminate the potential confusion. One approach would be to use different colour and line coding for the contact rings and range rings: for example, range rings might be solid lines of one hue and contact rings a broken or dotted line with a less conspicuous hue and luminance. Conspicuity should be reduced for the contact rings, no matter the type of coding, since the salient information is not the ring itself but the data attached to it. Another approach that might avoid any shape confusion whatsoever, is to use radial lines from own platform to indicate the bearing containing the data of interest. Again, such lines should have lower luminance, be broken or dotted, and/or subtly colour coded to avoid confusion and interaction with other more tactically salient display elements.

Whatever the actual implementation, care will be needed to avoid the possibility of screen clutter with implications for degraded operator performance in tasks such as search and detection. Attention should be given to developing an overall colour and luminance coding approach that will minimise the potential for clutter.

4.7.3 Overall workstation configuration

Given the planned change in operator manning of the new two-console TIAPS suite, some general workstation configuration and design issues will need to be examined. The analysis will not only need to look at the need for operators to interact between the TIAPS suite and other new or existing systems, but also the generic need for ensuring adequate design to support sharing information among other OR team members who will interact in and around the TIAPS system. While these exact functions remain to be identified, we know from prior analyses that team members group around displays to discuss and share content, interact with other displays to integrate relevant information and pass quickly written communications and notes (often of the "post-it" variety) on a frequent basis.

It is recommended that early in system development the issue of TIAPS function allocation between the two member team be examined and analysed and that the relationship between TIAPS functionality and other standalone systems be reviewed for potential impact on overall workstation configuration.

While a number of the above issues remain to be identified and analysed, we have made the following preliminary observations based upon the information obtained to date.

4.7.4 Ambient lighting

The overall OMI must be configured by taking into account the operational ambient illumination conditions. Low illumination, red lighting, sources of screen reflections and the potential for glare all will have an impact on the visual quality of the display. Hence, *usability analysis and evaluations of the OMI should generally be performed in a context that allows such conditions to be simulated*, otherwise the results may not be valid for operational conditions.

4.7.5 Screen configuration

If information is to be shared among the two operators by looking at each other's screens from time to time, or if other team members will need to look "over-the-shoulder" of seated operators, the off-axis viewing of the display becomes an important issue. Symbology, graphics and text will need to be designed in a manner to accommodate such conditions. Further, the potential use of LCD technology may exacerbate such problems.

4.7.6 Software navigation issues

By software navigation we are referring to the need for the operator to move purposely through the layers and menus of the system functionality and to manage windows in order to perform the required operational tasks.

One potential issue that may be readily identified is how the operator will be able to shift between different spatial mental models of the maritime picture. For example, the tactical display provides the operator with a high level view of the tactical situation showing an integrated view of the spatial relationship between important elements of the tactical environment. If operators are provided with a "zoom" capability that allows changing the scale of a subset of the tactical area there may be a need for the provision of separate windows for providing "ranged-in" and "ranged-out views. As a second example, if the operator wishes to explore certain aspects of a contact's acoustic data, then either passive or active display formats will need to be interrogated Since these formats are complex (and will presumably consume a large component of screen area), and require time to scroll through, explore and analyse there will be a risk associated with losing the tactical picture. This loss may take a variety of forms: it could be a complete or partial loss of important elements from the mental representation, or it could result in a failure to appreciate how the tactical picture may have changed in the time between the operator's last view of it and the return from using other display formats.

At this stage, this concern may only be a potential area to be flagged. Several design decisions could mitigate this risk. For example, in a two-operator/two workstation configuration, the tactical display could always be maintained on one of the operator's consoles. (This assumes that they would be sufficiently close together to allow appropriate viewing by the operator who may be working at the acoustic data level). Another approach would be to ensure that for each workstation that there is adequate screen size (or two screens) to always allow a dedicated area for the tactical display.

Notwithstanding this particular solution to a specific issue, there remains the overall problem to ensure that the operator's mental models and associated situation awareness are appropriately supported as the operator moves through different aspects of the system functionality, each of which provides data on different "world views". Loss of the picture, problems in regaining the picture and difficulty integrating spatial and other data across a variety of views of the battlespace has been identified as a major issue in the support of command situational awareness and decision making.

4.7.7 Sharing information

We have concluded from previous OR analysis (Matthews, Webb and Bryant, 1999) that OR team members frequently have the need to rapidly share spatial information. Sometimes this relates to discussing the content of each other's display, at other times it is the problem of how to integrate written or auditory data into the spatial domain of the user's current mental model. Some of the specific needs that have been identified include:

- Rapidly configuring two different displays to ensure a common displayed area of interest
- Tools for annotating another team member's display (e.g. to easily point to an object of interest)
- Tools for rapid sharing of spatially complex data (without having to revert to long and frequently inaccurate verbal descriptions)

These needs would also seem relevant to the future implementation of TIAPS as an operational system.

4.8 Future research and development issues for core TIAPS functions and related issues

On the basis of the information available at this stage of system development, the following critical functions or tasks have been identified as being candidates for future research and development effort. It should be noted that this list represents an initial assessment that will need to be updated and modified as the system evolves to the point where functions are allocated among the team members, and any new operational procedures have been identified.

4.8.1 Configuring the system

In TIAPS there will be a number of critical decisions to be made concerning system configuration. These not only include combining the existing configuration steps for separate active and passive systems, but also the implications of any interactions and synergies to be gained by the dual configuration as well as considerations of the roles to be played and tasks to be performed by the two sonar team members. No doubt, over time, standard configurations will be developed for particular missions, tactical contexts and water environments. While the task of configuring the system is unlikely to be performed under time pressure in most circumstances, it is one that will need to be performed with consistency and accuracy.

Suggested research needs:

1. Analyse the operator's tasks in configuring the system with a view to providing information for design concepts to optimising the consistency and accuracy of the process.

4.8.2 Operator interaction with automated functions

As has been indicated previously, the volume and scope of the data produced by TIAPS creates a serious challenge to the present approach in CANTASS for contact detection and analysis, whereby the operator scrolls through processed acoustic data on a beam-by-beam basis. The process would take too long to go through the entire beam array and important data may have arrived on any beam between each complete scan. As a consequence, TIAPS operates on the premise that certain detection and tracking functions must be automated and the operator will monitor the output of such processes. It should be remembered that this output will be dependent upon not only the characteristics of any acoustic sources within the detection range but also on how the automated processes have been configured. In the active mode, operators must select appropriate transmission characteristics for the expected targets of interest as well as configuring the transmission for the known characteristics of the water environment. The operator must also set up the criteria and parameters for automated detectors. The operator's choice of a transmission/detection model[4] is critical to system performance and represents an area of functionality that has not been investigated in the present study. This topic seems worthwhile for future analysis because of the potential complexity and criticality of the task. For example, setting the acoustic propagation model requires decisions on a very large number of parameters, the waveform data requires 14 parameters to be set, the wavetrain data -5 parameters, the ping bundle data -12 parameters, the ping sequence data-12 parameters. In all, there appear to be somewhere between 100 and 150 configuration parameters. While many of these will be pre-configured and pre-determined into a standard set of "models" based upon accumulated operational experience and the tactical situation, this type of function represents a complex series of critical tasks which will require close analysis to determine the best way to provide functions, tools and an OMI to allow the operator to perform tasks quickly and accurately.

On the acoustic reception side, the operator must make decisions on the influence of the water environment, local topography and range of interest. Hence, any auto-detection outcome will be influenced both by how well the system has been configured as well as the signal to noise ratio of the acoustic signal of interest. To state the obvious, the absence of a signal may mean either that there is no contact present or that the system has not been configured in a manner to detect the contact. Conversely, the presence of an auto-detected contact, may either be due to a real acoustic source of interest, or be due to the system mistakenly reporting signal in the presence of noise.

In deep water operations, where there is some predictability to the surrounding underwater environment and acoustic sources, an automated system may work with a high degree of effectiveness in yielding high hit rates while minimising false alarms and misses. However, in a littoral environment, particularly in areas with moderate to heavy vessel traffic, it may be unrealistic to expect that an automated system will operate with the same level of effectiveness. Ironically, it is exactly in such an environment where an automated system is needed the most, in order to reduce an unmanageable workload on the operator, because of the high volume of acoustic data to be analysed.

Operator evaluation of the detection model

In order to understand the output of an automated process in such a context, the operator (or, as it has been suggested, the supervisor) will have the task of establishing "what is the truth". There may be two possible approaches to this. First, the operator could systematically explore and evaluate the underlying acoustic data on which the automated decision has been made. (In the case of an auto-detected high threat target this kind of check will be likely mandated.) The task of selecting, scanning, interpreting and analysing the underlying data associated with the contact will be of necessity time consuming. In terms of system design, this suggests that there should be some thought given to how the underlying data may be readily extracted and presented in a format that enables rapid understanding and interpretation by the operator. A second method for establishing the validity of the contact, that may be more appropriate when the operator is looking at a contact summary report on a tactical display, would be to allow "what-if"

[4] The term detection model is for now being used as a shorthand to summarise all of the operator selected parameters, whether oceanographic, tactical or intelligence-based etc that will be required to configure both active and passive components.

exploration. This could involve giving the operator the ability to examine changes in the displayed plot of contacts by changing model parameters in real time. In this manner, the operator may be in a better position to analyse the degree to which the automated contact reports are influenced by critical changes in any of the underlying model parameters.

For either of these methods to be implemented, there will be a need for research into first understanding the cognitive tasks that the operator will need to perform to establish "truth ", and, second, developing display formats and interactive modes that support the operator's cognitive requirements.

Trust in automated processes

Experiences from other domains suggest that operator trust in automaticity is critical to both user acceptance and system performance. One aspect of this trust concerns the reliability of automated systems. Typically three kinds of unreliability have been reported, which tend to undermine human confidence. First, the automated processes may fail, since frequently they are more complex than the equivalent human activities (Wickens, 1992). Second, human operators may incorrectly (and unwittingly) configure system parameters (e.g. Stein, 1981). Third, the automated system performs as it is supposed to, but the operator fails to understand it and assumes that it is making errors (Woods, 1996).

In the case of automated sonar detection systems, errors are an inherent by product of any detection algorithm. Acoustic data are by their very nature uncertain and noisy and there will always be an overlap between the distribution of acoustic data that represent noise and the distribution of acoustic data that represents contact superimposed on noise. Thus, with any automated system designed to make decisions on "contact" or "non-contact" there will be errors depending upon where the decision criterion is placed. Errors will either be missed contacts or false positive identifications of noise as contacts. The frequency of such errors establishes the level of operator trust in the system. In existing operations using CANTASS, operators frequently turn off automated trackers, because they tend to *increase* workload by generating false tracks instead of reducing workload as intended. Further, recent studies show that operators may set the criterion threshold of an automatic detector and tracker to minimise workload rather than optimise performance (McFadden, Lauz and Stanger, in preparation)

Even if new generations of detectors and processing algorithms reduce the number of perceived operational errors, there remains the possibility that another problem associated with human trust might emerge, namely overconfidence or reliance. Some of the issues of operator overconfidence in system automation that give rise to complacency and lack of vigilance (Parasuraman, 1986), would not seem to be applicable to the potentially high threat context of many naval subsurface operations. However, research which shows a loss in situation awareness, when operator's cease to become active processors of data and over rely on automation (Hopkin, 1996) may be relevant. This may produce some somewhat contradictory guidance for the adoption of automation, since if operators alone are required to process all of the sonar data without machine assistance, this in itself will tend to inhibit the formation of situation awareness. Operators may tend to spend too much time "in the weeds" without seeing the larger tactical picture. Traditionally, this problem has been solved by role differentiation within the OR team hierarchy, whereby operators detect, identify and to some extent classify and feed the processed information to higher levels in the command team to build the tactical picture.

The research literature also shows that operator trust in automated systems is frequently out of calibration and there is reported evidence of both over-trust and mistrust. Humans tend to trust their own performance over that of automated systems, even when the automated system performs at, or better, than its human counterpart (Liu, Fuld and Wickens, 1993). In particular, the literature on mistrust of alarm systems may be particularly relevant to automated sonar detectors that are designed to alert the operator to hostile or other potentially threatening contacts of interest. This literature shows that operators may so mistrust unreliable warning systems that legitimate warnings are ignored (Sorkin, 1988).

While proper training and operational experience may reduce some of the problems associated with trust and interpretation, there will remain the requirement for the operator to be able to interrogate the veracity of any automated process. Hence, in designing the system some consideration may need to be given to providing information to the operator concerning the implications of the chosen decision criterion for generating false positive or missed contact errors, particularly as a function of the influence of the local environmental conditions. McFadden, Vimalachandran and Blackmore, (2001) showed that subjects in a simulated sonar detection and tracking task failed to detector errors by the automated detector and tracker. They suggested that such failure was due largely to the lack of visibility of the automation errors relative to other errors. They further showed that people could make reasonably effective use of an automated tracking system, if they receive extensive experience with it. However, just training people on the associated manual task appeared to be of little benefit. Thus, it seems desirable to provide operators with some easily comprehensible feedback on probability of each error type for the given context, and to ensure that they are appropriately trained to actually use this information in under actual operational conditions. This training would involve developing skills at setting appropriate criteria for the context, monitoring the system for automation errors and interpreting the operational significance and reliability of the data obtained from automated processes.

Some general principles for improving the trust between the human operator and automated processes are:

- Keep the human informed by advising what the automation is doing through readily comprehended displays.
- Keep the human trained in order to maintain the necessary skill level
- Keep the operator in the loop. Getting the right level of operator involvement represents a significant design challenge to avoid the extreme conditions of operator overload and underload and complacency.

- Make the automation flexible and adaptive in order to allow for different levels of operator involvement depending upon the workload demands of the context and to accommodate differences between operators.

Suggested research needs:

1. Analyse the operator's tasks in configuring automated processes and comprehending of the impact of the configuration setting upon the expected data.
2. Analyse the operator's understanding of the performance tradeoffs associated with criterion settings for automated functions. (Note: this will require that appropriate prototype system functionality be in place to create the necessary test capability. Such functionality would then be re-configured in system development as part of a recursive process of test and evaluation).
3. Conduct research on the best way to provide a visual or data representation of the information that will support the operator's mental model for making effective decisions concerning both of the above areas.
4. Perform a literature review to determine whether there is relevant research in other domains concerning operator trust in, and interaction with, automated systems with a view to acquiring guidance on specific design solutions that address issues of operator trust and performance.

4.8.3 Displaying the tactical underwater environment

Existing passive and active displays of process sonar data do not lend themselves well to rapidly producing a level of understanding or comprehension in the sonar operator (NATO IST-13/TG-002, 1999). Existing displays require operators to perform labour intensive tasks to analyse and transform data in order to comprehend its significance. Further, it will be particularly important for operators to have a clear and rapid understanding of the underwater environment for operations in the fast changing context of a littoral environment. Recent papers (e.g. Wright, 2000) suggest new ways of modelling the underwater environment to assist the process of visualising aspects of the topography, water and temperature layers and tactical context. These methods provide the operator with a visual model of the environment that maps more directly on to their cognitive framework than traditional displays. One application area that could be developed concerns new display formats that show acoustic propagation and dispersion data (either active or passive) superimposed upon topographical and water layers as a 3d model. Given that it is important that the operator understand how these elements influence the sonar data that is obtained, such a display format might more easily support the operator's mental model of the UW environment. This could also be refined to incorporate aspects of the acoustic volume analyser (Wright 2000).

Suggested research needs:

1. Conduct a cognitive task analysis to determine operator needs for comprehending the underwater environment.
2. Review literature on visualisation techniques for representing the underwater environment.
3. Evaluate data formatting and presentation options for optimising visualisation of the underwater environment, including colour coding and 3d representations.

Suggested design/development needs:

4.8.4 Operator interaction with the tactical display

In this section we speculate on the multiple roles that could be played by the tactical display in supporting UW picture compilation and tactical decision making. By examining possible worst-case scenarios for the use of the tactical display at this stage in system development, we flag opportunities to conduct appropriate research and design activities at the appropriate stage of system evolution and before operational introduction.

At present it is not known how the UW team responsibilities may change with the introduction of TIAPS. However, for present purposes, it may be appropriate to consider that the ASWC will retain the responsibility of working with the ORO at the tactical decision making level, while the team below the ASWC ensures that the appropriate and correct UW picture is being fed to the command level. Hence, a critical common point of focus between the ASWC and other team members (probably the supervisor) becomes the tactical display. While the ASWC may have an additional tool suite to configure the tactical display to assist tactical decision making, the basic UW picture will be determined at the supervisor level. Thus, all contacts that are displayed will need to have been appropriately analysed and annotated. Further, if the intention is to use the tactical display for showing the RMP, every contact will need to be identified. Thus, one role for the common tactical display is to represent the RMP.

A second role of the tactical display is to present to the operator the ongoing data associated with automatic contact detection and tracking systems. The operator will have the task of searching for new contacts (which will become increasingly complex with larger numbers of targets and busy littoral environments) and ensuring targets are appropriately tracked.

A third role of the tactical display may be to allow the operator to conduct some forms of analysis concerning the veracity of auto-detected contacts, as well as to identify, localise and classify. In this role, the tactical display and associated tools provide the operator with the capability of looking at the relationship between contacts and other relevant elements from the UW environment.

A major difficulty can be foreseen in the interaction of the different display requirements for these three different roles. For detecting new contacts, the supervisor will need the symbology that facilitates rapid localisation of the contact on the display. For analysing the contact, the supervisor will need to rapidly access contact characteristics and compare these with associated or correlated data available through other display formats (e.g. broad band). For building the RMP, the supervisor will need to ensure that each track is appropriately configured and annotated. A scenario could be envisaged in a busy littoral environment, where scores of auto-detected contacts are plotted on the display already populated with track data as part of the RMP. The operator may face two major challenges such circumstances. First, the task of detection new contacts may be visually challenging among the clutter; second, if the operator changes focus from the tactical display to the task of analysing acoustic contacts using other displays, it may be difficult to determine what has changed in the tactical display when it is again the focus of attention.

The information requirements that subserve each of these functions to be performed using the tactical display are likely to be different since they involve all of the different perceptual operations outlined in IST-13/TG-002 (1999), i.e. controlling/monitoring, alerting, searching and exploring. Examples of these are:

- *Monitoring*: sampling the surrounding acoustic environment to monitor variables that influence model parameter values.
- *Controlling*: building the UW RMP
- *Alerting*: scanning the display for high threats or pop-up contacts
- *Searching*: scanning the display for new contacts displayed as output from automated processes
- *Exploring*: broadly searching the tactical area of interest to gather information on any new data of interest that might influence the tactical picture or enhance processes of identification and classification.

As stressed in IST-13/TG-002 (1999), these different perceptual processes each require different forms of data display, transformation and coding in order to support rapid and accurate comprehension of the information.

Finally, given the many potential roles to be performed by the tactical display, it seems likely that the operator or supervisor will be faced with new tasks associated with display management. While this may be considered a minor issue at the present stage of development, other complex systems which use multiple display formats on a single physical display have been shown to induce user confusion and resulting performance errors, typically when operators are under stress and have moderate to high workloads (Sarter and Woods, 1995).

> *Suggested research needs:*
>
> 1. Develop mission scenarios for assessing the impact of TIAPS on future operations.
> 2. Perform further task and function analysis to determine the operational functions to be performed by the UW team (ASWC, Supervisor, Operator) using the tactical display. In particular determine whether the UW RMP will be compiled on the display, and who in the team will have the responsibility for this task.
> 3. Develop a taxonomy of user visual performance tasks and modes of data representation to provide guidelines for appropriate display formats and configurations.
> 4. Determine the degree to which the potentially different representations for the tactical display can be accommodated within a single window format, or whether multiple representations are required.

4.8.5 Communicating spatial information

Many of the tactical decisions, whether in the underwater or above water domain, depend upon a rapid comprehension of elements of time and space within and across team members (Matthews, Webb and Bryant, 1999) and current C2 technologies in the CPF do not support this function well. Frequently, the team mental model of the tactical situation requires a common understanding of spatial information that can be readily visualised. Team members may also need to share a common picture, often from a common perspective (e.g. range, zoom and point of focus) with common elements integrated with individual annotations that are relevant to understanding the situation and deciding among action options. As new technologies like TIAPS

> *Suggested research needs:*
>
> 1. Perform cognitive task analysis to determine the shared information needs among UW team members and higher command levels.
> 2. Determine whether existing guidelines are adequate for determining the specific format and structure of data representations to facilitate rapid spatial information sharing.
> 3. Empirically evaluate effective means of visually representing common information based upon guidelines or, if required, new research initiatives.
> 4. More generically, conduct research on how team members communicate and share spatial information and the nature of internal representations and develop conceptual models and guidelines.

migrate into the operational environment, with their improved capability for displaying common information and sharing data among the command team and lower levels in the hierarchy, an opportunity exists to provide improved functionality for sharing spatial information.

4.8.6 Function allocation and UW team composition

At present, as a technology demonstration project, there has been a focus in TIAPS on providing new tools and functionality to assist sonar operations. Some decisions have been made concerning the allocation of functions to machine or human that are thought to optimise the roles of each. These decisions have been made in a system development context rather than as a result of a formal function allocation exercise. The future structure of the sonar team and its relationship to the command level structure is also not known at this time, although there is persistent speculation that the number of personnel in the future is likely to be lower than at present. Given the potentially broad range of functionality provided by TIAPS and the need to consider a more streamlined personnel environment, there will soon be a critical need to assess function allocation not only between machine and human, but also among the team members. It is possible that some tasks now performed at the ASWC level or by other sonar team members (e.g. building the RMP, localisation and TMA) will need to be performed within the TIAPS team. To assist the process of determining the implications of different allocations, task network modelling of different arrangements is recommended.

Suggested research needs:

1. Develop a task network simulation of the TIAPS functions, including other generic UW C2 functions as necessary.
2. Evaluate the impact of different numbers, roles and responsibilities of the UW team composition on information flow, workload and the performance of critical tasks.
3. Determine the optimum composition of the UW team and functions assigned to each team member.

4.8.7 Miscellaneous display issues

As outlined in the heuristic review of the tactical display a number of research and design issues were identified and these are summarised below.

Suggested research needs:

1. Do link analysis and other relevant analyses to determine optimal workstation layout
2. Evaluate impact of LCD technology for off axis and low illumination viewing
3. Develop guidelines for OMI style for LCD technology, in particular, taking into account issues of display resolution, colour coding, text and symbology.
4. Determine appropriate screen layouts, formats and navigation for supporting TIAPS functionality.

5. Discussion

In considering the analysis of OMI issues relating to TIAPS, it must always be remembered that TIAPS is a technology demonstration in an ongoing state of development. Unlike a commercial product, which is designed to pre-determined specifications, TIAPS represents a research and development vehicle to assess the feasibility of new approaches to sonar data processing. A major question is then - at what stage of maturity of development does it make sense to conduct function analysis, specify critical tasks and evaluate the OMI? If performed too early in system development the analysis may be inappropriate in that the functionality and technology at the time of the analysis may only represent interim working ideas that will give way to possibly new directions. If performed too late, then hard design decisions may have been made without considering the role of the user, and which may be costly and impractical to undo.

While it may be argued, that the function analysis should be independent of the system, radical advances in technology may profoundly influence what functions a system can perform, which in turn impact upon the operator's tasks. Further, new technologies may so transform the situation that they will inevitably impact upon doctrine, staffing, function allocation and operational procedures. Thus, it would appear that one can never fully separate the "true" system functions from the underlying technology. What the operator can and will do will always to some extent depend on the capabilities of the technology. This means that mission, function and task analyses may become continuing and iterative processes throughout system development in contrast to the traditional approach of doing them early and one time only. However, one would expect that with each iteration, the analysis would be refined rather than redone (with consequent reduction from the initial level of effort) and at the mission analysis level there may be little need for more than one or two iterations. In general, to define the basic functions of military C2 systems that embrace revolutionary technology, means that there has to be a continuing high level of synergy during the development and evaluation process among the technology designers, research scientists, human factors specialists and military users. Among the latter it will be necessary to engage involvement of SMEs with a range of perspectives, including the doctrinal, the procedural and the operational, that may be impacted by technological considerations.

If one regards the present analysis as being the first step in the iterative function specification cycle, then given that there has been significant interaction with scientific and development SMEs, and some access to current TIAPS functionality, it may be reasonable to conclude that the timing is appropriate. At this stage, the system concept is reasonably well defined, core functionality is in place and operational trials to assess the technical aspects of sonar data processing are in progress. Having said this, it should be noted that the primary focus in the short term among the TIAPS team is to evaluate the major steps forward that have been taken with new technology. The role of the operator right now is more of a product tester than an operational sonar operator. As such, the OMI, at this stage of system development, may only need to be sufficient to enable the collection of acoustic processing performance data.

Following the earlier argument, it should be concluded that the function and heuristic analysis represents an interim evaluation of TIAPS. Sufficient functionality exists in concept form to comment upon how it may be structured to perform operational tasks. Limited interactive

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functionality also permits some initial evaluation of OMI concepts. Instead of regarding the current analysis as a final statement on TIAPS, it should be seen against the context of the general development philosophy of "build a little, test a little" - to which we should probably add the phrase "analyse a little". If the existing functionality undergoes major changes in development, it may be necessary to revisit the function analysis. Certainly, as new functionality is translated into working interfaces, additional OMI evaluation will be required. Such future work will be facilitated by the existence of the present analyses. The function analysis provides a basic structure on which to build future elements and change relationships among existing functions. The heuristic review of the OMI has produced some principles that should generalise to future work. Perhaps, the most significant impact on the need for future function analysis will come from an operational review of how TIAPS functionality will actually be adapted in the OR.

This larger issue of how TIAPS will fit in with new command philosophies, tactical doctrine, team roles, responsibilities and personnel levels will have a major influence on how TIAPS functionality will be actually implemented. For example, with a smaller team and responsibility for creating the UW RMP delegated downwards, the role of the sonar operator will be very different from existing practices. As a consequence, the functions and underlying tasks will change. This will require not only revision of the function analysis but will have implications for function allocation and the design of the tactical display. To some extent this report tries to anticipate such possibilities and therefore flags issues in OMI design that may need to be considered to meet such needs. However, given the radical departure from existing operator tasks and practices that could be envisaged with TIAPS, there will be a critical need to evaluate candidate OMI designs in an evolutionary manner - from storyboard through field testing (Matthews, Webb and McCann, 1997). At present, such a process does not appear to be on the horizon of TIAPS development, given the interim focus on ensuring that the underlying technology is sound.

Finally, there will be a need for Navy involvement in defining what role they want the sonar operator to play, in the light of the functional design philosophy that is involving under TIAPS. The current design solutions have significant implications for manning, job role definition and training of the UW team in the Ops Room. Failure to bring the operational and design perspectives together at this time of system development may lead to a fundamental conflict between technology and command authority . (Pigeau and McCann, in preparation). A development strategy in which there is an over-emphasis on advancing specific sonar technologies without a parallel consideration of how solutions might impact on the structure of the operations room creates an environment where such conflict is likely to emerge. Failure to recognise the operational implications of current design decisions will lead to the operator not using the system to its full potential, just as certainly as poor design of the interface. An example of this is the failure of operators to make effective use of the current automation capability in the CCS and CANTASS.

In contrast, the bringing together of Navy operational interests and HF analysis and evaluation with the main thrust of the technology development has the potential to yield many benefits. Navy analysts will have an early appreciation of how the new technology will impact on operational procedures and can consequently feed back to the development team how the system functionality may need to be configured to meet new procedures and manning. The HF role will be to interpret the human performance considerations that derive from the ensuing functions in terms of analysing tasks, assessing function allocation trade-offs between the operator and the system and advising on resulting OMI issues that will be critical for effective human-system performance. Early and ongoing involvement of the three groups will also ensure that design options are considered and evaluated before system functionality becomes too firmly established with the inevitable higher level of effort and costs for revision.

The complexity of the technology and its potential to be a revolutionary rather than evolutionary approach to UW warfare demands such a synergistic approach to system development that falls outside the norm of typical commercial product development strategies. The successful evolution of system functionality will be dependent upon the ability to bring together the design and build process with test, evaluation and *research* activities. While some of the questions concerning function allocation and OMI design can be anticipated and answered within the existing knowledge base, many other questions will require that system functions be analysed with human-in-the-loop tasks and experimental protocols. This analysis may then uncover issues for which there needs to be some core HF research in order to provide data to inform the optimum design solutions. Further, at some point in system development there will be a need to obtain estimates of human workload issues and performance capabilities for critical tasks by evaluating design alternatives and function allocation trade-offs using methods such as task network simulation. The resulting information will provide meaningful feedback to both functional design and detailed OMI design.

Let us now summarise and review the major issues revealed by the HF analyses in terms of the core critical tasks and functions.

One of the largest issues concerns the role and performance of the operator in working with an automated system. Experience in other domains shows that automation, while often reducing some forms of workload for the operator, creates other impairments to effective human-system co-operation. Experience in CANTASS, where some of the automated functions are not used by operators, is consistent with automation research that shows users will not use automated systems unless they are perceived as trustworthy and as reducing workload. The report identifies several related issues that will need detailed design attention as the system evolves. These include operator trust in automation, operator configuration and analysis of automated processes, and the shift from the current role of the operator as an active data processor to the role of part active processor and part system monitor. Careful review of these areas will be needed to ensure that the appropriate functionality is in place to meet the operator's needs and that the functionality is supported by an OMI that allows rapid comprehension by the operator of critical information.

A second major area concerns the configuration of system models and interpretation of their performance. While this is not a new functionality in sonar operations, it does represent a core process for elements of both active and passive sonar analyses. There is a requirement for operators to be able to configure effectively and to readily understand the implications of choices that are made. The criticality of this task will be enhanced with future operations in littoral contexts.

A third area concerns the function and design of the tactical display. It has been shown that the inherent flexibility provided by the functionality of the tactical display, means that the display will be useful for a range of operational tasks. However, each of these tasks may require different design approaches to the OMI. A format that is optimised for building the RMP may be inappropriate for detection of contacts, classification or tactical analysis. A balanced and flexible design approach will be required to ensure that in making the tactical display serve a broad variety of needs that it also supports in an optimum manner any specific need. Additional analyses will be needed to uncover the specific design requirements, once operational functions for the display have been explored and determined.

A fourth area concerns how the overall workstation configuration and each functional window will be integrated to serve operational requirements. Of concern is the loss of situational awareness that can occur when an operator has to switch between types and levels of display information. For example, the operator may "lose" details of the tactical picture when doing tasks that involve analysis of processed sonar data, association, track management or TMA. Further, when trying to regain the tactical picture after performing such tasks, the operator has to have a rapid comprehension of what has changed. While some of these issues may be resolved by assignment of different and specialised roles for each of the UW team members (as is presently the case), the convergence of powerful functionality within the TIAPS suite together with a reduction in personnel will inevitably result in an environment where operator multi-tasking becomes the norm.

A fifth area deals with general screen design issues. While ultimately individual screen designs will be dictated by the specific operational tasks that will emerge, certain issues can be identified at this stage in system evolution. First, there are basic symbology, data and colour coding issues that will be influenced not only by operator needs but also the display technology adopted. Second, there are more generic issues about how to design displays that support tasks such as setting and interpreting system models and evaluating the performance of automated systems. Third, there are issues about how to improve operator visualisation of the underwater physical environment both from the perspective of analysis of sonar performance and evaluation of the tactical situation. This need will become more critical with operations in littoral environments. Fourth, there is a need to provide tools that will improve the effectiveness of the conduct of tasks such as contact identification, localisation and classification to take advantage of the improvement in the underlying acoustic data that TIAPS will afford. References are provided in the text for some generic guiding principles that address OMI design to support user comprehension of spatio-temporal information through visualisation (e.g. NATO IST-13/TG-002, 1999). However, research in this area is insufficiently developed at this stage to provide the TIAPS team with concrete guidelines for specific display design.

To continue this theme, the report notes a number of areas where future research is needed in order to provide data and recommendation to support TIAPS design and development. It is also recommended that some of the design options, alternatives for function allocation to system and operator (and between operators) be analysed using a task network simulation.

Finally, it is recommended that the functional analysis and OMI review be considered integral to the future design and development cycle of TIAPS. The present analysis provides a foundation and structure to facilitate such future tasks. However, as operational considerations start to shape the roles to be played by the UW team using a future version of TIAPS, as new core functionality emerges, and as tools and features for analysis and interpretation of sonar data are developed, there will be a need to ensure that appropriate HF analyses are performed of the OMI. This will typically involve an iterative process through storyboarding of early concepts, interactive user evaluation of interim design solutions and empirical evaluation of prototype systems with human in the loop tasks.

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6. Summary of Recommendations

In this section recommendations made in the previous section have been re-organised, prioritised and in some cases augmented with points arising from some of the issues raised in the Discussion. The recommendations are organised into three broad categories directed towards defence research establishments (sonar system and human factors specialists), system developers and the Navy. Within the section of recommendations to defence scientists, three broad categories of priorities are suggested. Within the other sections, items are listed in an approximate order of descending priority.

It should be recognised that one danger in organising the material in this manner is that the different groups will only heed the issues that are addressed in their own sections. As has been stressed earlier in the discussion, the successful resolution of many of these matters is not the responsibility of a single community, but an ongoing partnership between all parties in which there is a reciprocal exchange of information and ongoing collaboration in finding solutions to complex problems that cut across the different domains.

Defence Research Establishments

Priority 1

Analysis Requirements

- Analyse the operator's tasks in configuring automated processes and comprehending the impact of the configuration setting upon the expected data.
- Analyse the operator's understanding of the performance tradeoffs associated with criterion settings for automated functions.
- Perform further task and function analysis to determine the operational functions to be performed by the UW team (ASWC, Supervisor, Operator) using the tactical display. In particular determine whether the UW RMP will be compiled by members of the sonar team using the TIAPS tactical display, and (in collaboration with the Navy) who in the team will have the responsibility for this task.
- Develop a task network simulation of the TIAPS functions, including other generic UW C2 functions as necessary.
    - Evaluate the impact of different numbers, roles and responsibilities of the UW team composition on information flow, workload and the performance of critical tasks.
    - Determine the optimum composition of the UW team and functions assigned to each team member
- Perform cognitive task analysis:
    - Determine operator needs for comprehending the underwater environment.
    - Determine the shared information needs among UW team members and higher command levels.

Research requirements

- Conduct research on the best way to provide a visual or data representation of the information that will support the operator's mental model for making effective decisions concerning the configuration and evaluation of automated functions.

Direct Design Support

- Develop a taxonomy of user visual performance tasks and modes of data representation to provide guidelines for appropriate display formats and configurations.

Priority 2

Analysis Requirements

- Analyse the operator's tasks in configuring the system with a view to providing information for design concepts to optimising the consistency and accuracy of the process.
- Do link analysis and other relevant analyses to determine optimal workstation layout

Research requirements

- Perform a literature review to determine whether there is relevant research in other domains concerning operator trust in, and interaction with, automated systems with a view to acquiring guidance on specific design solutions that address issues of operator trust and performance.
- Review literature on visualisation techniques for representing the underwater environment.
- Evaluate data formatting and presentation options for optimising visualisation of the underwater environment, including colour coding and 3d representations.
- Conduct research on how OR team members communicate and share spatial information, the nature of internal representations and mental models and develop conceptual models and guidelines.
  - Determine whether existing guidelines are adequate for determining the specific format and structure of data representations to facilitate rapid spatial information sharing among the OR teams.
  - Empirically evaluate effective means of visually representing common information based upon guidelines or, if required, new research initiatives.
- Evaluate the optimum configuration of display functionality (number and arrangement of monitors, types of display windows, composition of window elements) that supports effective execution of individual team member functions.
- Evaluate impact of LCD technology for off axis and low illumination viewing.
- Review literature and/or conduct research on loss of situation awareness when operators must perform multiple tasks in a multi-display/multi-window environment.

Direct Design Support

- Analyse the outcome of the literature review on operator interaction with automated processes to provide feedback to system developers

Priority 3

Analysis issues

- Determine the degree to which the potentially different representations for the tactical display can be accommodated within a single window format, or whether multiple representations are required.

OMI Design Issues

- Generally, work with system developers to develop an OMI style guide to cover the standard areas plus the following specific issues.
    - guidelines for the use of colour and symbology, data formatting, layer filtering for the tactical display.
    - guidelines for display management
    - guidelines for LCD technology, in particular, taking into account issues of display resolution, colour coding, text and symbology.
    - appropriate screen layouts, formats and navigation for supporting TIAPS functionality.

System Developers

- Develop design solutions that allow flexibility in the assignment of responsibilities between operators and automated systems.
- Provide functionality that allows operator's to easily comprehend and evaluate the impact of parameter and criterion settings of automated processes on the data obtained.
- Integrate the results of HF and other operational analyses into functional system design.
- Develop functionality for visually evaluating the underwater environment for propagation, transmission and other forms of analysis.
- Develop functionality that allows operators to comprehend the integration of contact and track data with a visual representation of the underwater environment.
- Integrate the output of HF and operational analysis of the role of the tactical display into design solutions that optimise the format of the OMI for different tasks.
- Design the overall display configuration to allow the operator to maintain the relevant situation awareness when multi-tasking and using different display windows.
- Develop interfaces that allow rapid selection of pre-configured system models based upon contextual requirements.

- Use the output of link analysis to optimise the physical layout of the dual workstation configuration.
- Develop OMI style guide for UW tactical displays.

Navy

- In general, evaluate the operational implications for the future roles of the UW team in the light of the design decisions made concerning the core TIAPS functionality. This will include:
    - Manning levels
    - Responsibilities of the supervisor and operator
    - Relationship to the functions performed by the ASWC
    - Revisions to operational procedure and possibly doctrine
    - Training requirements
- Review existing operational problems and effectiveness in the use of automated functions to support command decision making in general and sonar analysis specifically.
- Consider the implications of the heightened role of automated functions in TIAPS for operational procedures and training.
- Consider the placement of responsibility in the UW team for the tasks of developing the UW tactical picture and compiling the RMP in the light of the tactical display capabilities of TIAPS.
- Develop mission scenarios for assessing the impact of TIAPS on future operations.
- Have ongoing involvement with system designers, developers and defence scientists with a view to optimising a cycle of design-build-analyse in order to identify core operational issues.
- Develop a test bed capability to assess the effectiveness and operational consequences of automated aids to command decision making and sonar analysis.

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ANNEX A:

LITERATURE REFERENCES

Annex A: Literature References

The following represents a full listing of relevant articles that were reviewed at some level as part of the literature review.

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ANNEX B1:

CANTASS FUNCTION DESCRIPTIONS

Annex B1: CANTASS Function Descriptions

Name of Function

1.1.1b RECEIVE AND PROCESS INTELLIGENCE INFORMATION

Missions Under Which Function Occurs

The Generic ASW Mission

System Units Which Support Function

No specific CANTASS systems are involved

Superordinate Functions

1.1 CONFIGURE ARRAY and 1.3 SEARCH FOR THREAT TONALS

Sequential Categorisation of Functions

Discrete, concurrent

Estimate of Criticality of Function

This function plays a large part in determining the correct set up of the array receiver, tracking, and signal processing parameters and affects the subsequent detection process. Subsequently (as a sub-function of 1.3), it is also extremely important in focussing the search for particular tonals—given that they have been detected by other sensors

Critical Variables

(i) own ship speed

(ii) own ship manoeuvres

(iii) weather conditions

(iv) oceanographic conditions

(v) make-up of convoy

(vi) speed of advance of task group and task group manoeuvres

(vii) availability of Helo/MPA support

(viii) availability of other surface sensor support

(ix) target speed

(x) target range

(xi) target aspect

(xii) intelligence on target

(xiii) contact held by other sensor

(xiv) communications status

(xv) task group command priorities

(xvi) number of targets

Required Quality of Output for Function

It is important to gain accurate information to allow optimal setting of the array and signal processing parameters.

Estimate of Probability of Failure to Complete a Function

Information may be incomplete

Consequences of Failure to Complete A Function

Failure to have adequate intelligence information would probably result in a failure to set optimal parameter values.

Failure to use intelligence (in proportions commensurate with its reliability) will result in inefficient use of all available information

Estimate of Time to Completion

Will vary according to the information source. None of the information collection will directly involve any member of the on-watch CANTASS team.

Sub-functions Or Tasks

TBD

Sequencing of Sub-functions or Tasks

TBD

Allocation of Function to Man, Software or Hardware

MAN

Interdependency of Functions

The output of this function will directly affect the functions SET ARRAY RECEIVER PARAMETERS (1.1.3) and SET SIGNAL PROCESSING PARAMETERS (1.1.4), as well as ADVISE ON SCOPE AND DEPTH OF ARRAY (1.1.2).

Successful completion of this function has consequences for all the functions that involve human input during the mission.

Name of Function

2.2. LOCALISE TARGET

Missions Under Which Function Occurs

The Generic ASW Mission

System Units Which Support Function

TBD

Superordinate Functions

2 CLASSIFICATION AND LOCALIZATION

Sequential Categorization of Functions

This function is continuous

Estimate of Criticality of Function

Essential in order to effectively prosecute target

Critical Variables

own ship speed

own ship manoeuvres

oceanographic conditions

make-up of convoy

speed of advance of task group and task group manoeuvres

target speed

target range

target aspect

intelligence on target

contact held by other sensor

communications status

task group command priorities

number of targets

Required Quality of Output for Function

Must be accurate to avoid missing a target.

Estimate of Probability of Failure to Complete A Function

TBD

Consequences of Failure to Complete A Function

Failure to localise the target may result in missed targets.

Estimate of Time to Completion

TBD

Sub-functions Or Tasks

The sub-functions for LOCALISE TARGET are:

2.2.1 RESOLVE BEARING AMBIGUITY

2.2.2 GENERATE AREA OF PROBABILITY FOR LOCALISING TARGET

2.2.3 UPDATE TARGET DETAIL

Sequencing of Sub-functions or Tasks

See flow chart above

Allocation of Function to Man, Software or Hardware

MAN

Interdependency Of Functions

Unless this function is completed the true bearing of a possible threat will remain dangerously unknown. In most cases, LOCALISE TARGET (2.2) will be completed before PROVIDE INFORMATION FOR TMA (2.8) will be started—although depending on the situation, the Ops Room may call for TMA information on an ambiguous track.

Name of Function

3.2 DETECT TORPEDO LAUNCH

Missions Under Which Function Occurs

The Generic ASW Mission

System Units Which Support Function

TBD

Superordinate Functions

3.0 SUPPLY TRANSIENT, IRREGULAR, TONAL INFORMATION FOR MPA/HELO OPS

Sequential Categorization of Functions

This function is discrete

Estimate of Criticality of Function

- Critical to avoid torpedo prosecution
- Once detected, the critical first task is to resolve ambiguity; this is usually through a best guess based on intel, since the signal information itself is not usually useful in providing clues.

Critical Variables

own ship speed

own ship manoeuvres

weather conditions

oceanographic conditions

make-up of convoy

speed of advance of task group and task group manoeuvres

availability of Helo/MPA support

availability of other surface sensor support

target speed

target range

target aspect

intelligence on target

contact held by other sensor

communications status

number of targets

Required Quality of Output for Function

High quality—torpedo must be detected to allow appropriate short term tactical decisions

Estimate of Probability of Failure to Complete A Function

- the signature is difficult to localise – it appears only in broadband
- operators have to rely on contextual information
- information rates are very high
- few operators have had opportunity to witness live signature

Consequences of Failure to Complete A Function

Undetected torpedo

Estimate of Time to Completion

TBD

Sub-functions Or Tasks

?1.3, 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7

Sequencing of Sub-functions or Tasks

TBD

Allocation of Function to Man, Software or Hardware

MAN

Interdependency Of Functions

TBD

Name of Function

4.0 SUPPORT SURFACE PICTURE

Missions Under Which Function Occurs

Generic ASW mission with silent radar

System Units Which Support Function

TBD

Superordinate Functions

Sequential Categorisation of Functions

TBD

Estimate of Criticality of Function

TBD

Critical Variables

own ship speed

own ship manoeuvres

weather conditions

oceanographic conditions

make-up of convoy

speed of advance of task group and task group manoeuvres

availability of Helo/MPA support

availability of other surface sensor support

target speed

target range

target aspect

intelligence on target

contact held by other sensor

communications status

number of targets

Required Quality of Output for Function

TBD

Estimate of Probability of Failure to Complete A Function

TBD

- Note: Operators are less well-trained in recognition of surface vessels and also the database of known signatures is less complete

Consequences of Failure to Complete A Function

Inability to built picture of surface group

Estimate of Time to Completion

TBD

Sub-functions Or Tasks

1.2, 2.1, 2.2, 2.3, 2.4, 2.6

Sequencing of Sub-functions or Tasks

Allocation of Function to Man, Software or Hardware

MAN

Interdependency Of Functions

This function will be affected to some degree by CONFIGURE ARRAY (1.1).

Name of Function

5.0 PREPARE OCEANOGRAPHIC BRIEF FOR CO

Missions Under Which Function Occurs

The Generic ASW Mission

System Units Which Support Function

None directly

Superordinate Functions

Sequential Categorization of Functions

This function happens once a day with a 24-hour overview.

Estimate of Criticality of Function

Important to keep CO informed of mission progress.

Critical Variables

Required Quality of Output for Function

Accuracy is important because the brief will influence decisions on how to proceed on mission.

Estimate of Probability of Failure to Complete A Function

This is a required task under standard operating procedures, probability of failure is virtually zero.

Consequences of Failure to Complete A Function

CO and OR teams may not receive critical information

Estimate of Time to Completion

1 hour to prepare and ½ hour to present

Sub-functions Or Tasks

Sequencing of Sub-functions or Tasks

Allocation of Function to Man, Software or Hardware

MAN

Interdependency Of Functions

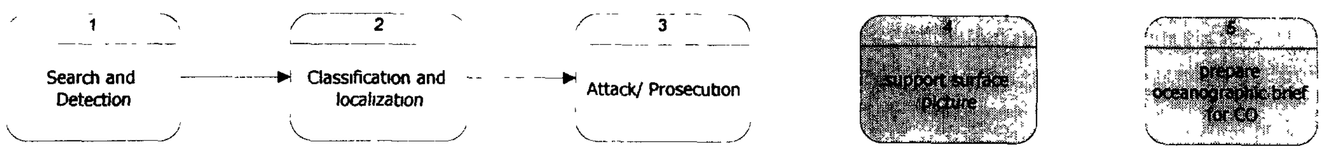
ANNEX B2:

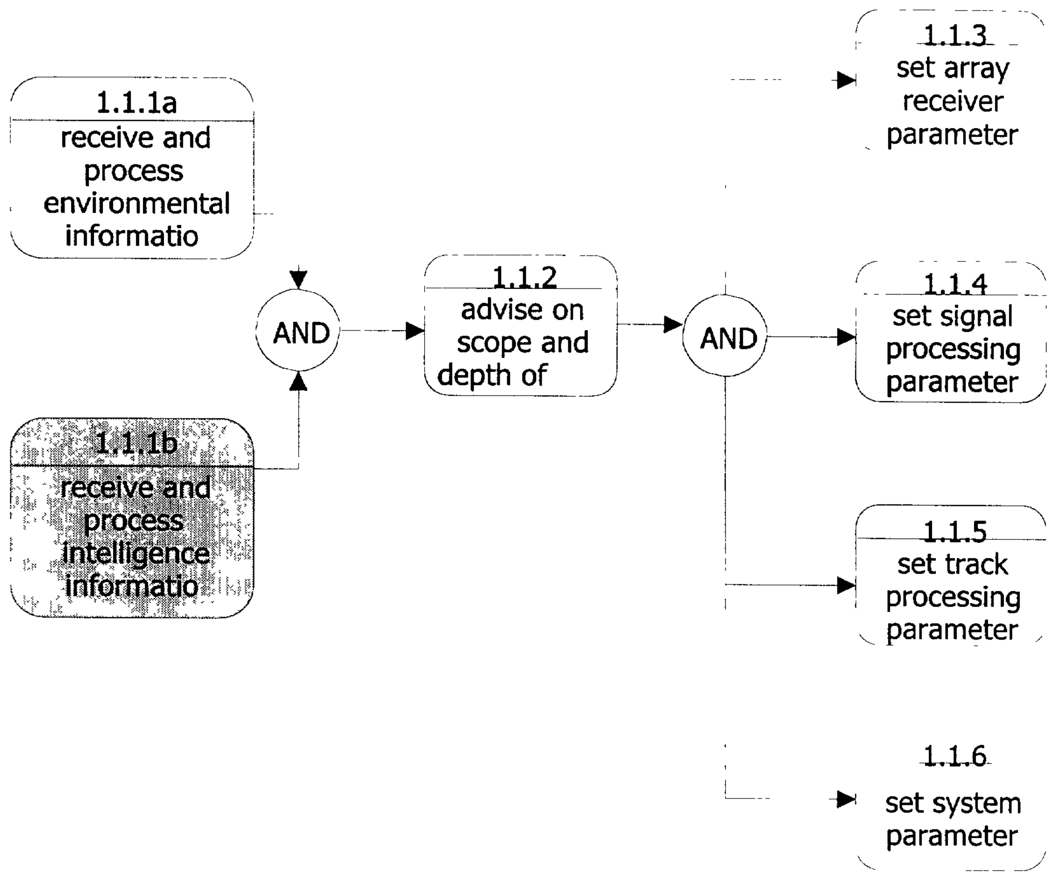
CANTASS FUNCTION FLOW DIAGRAMS

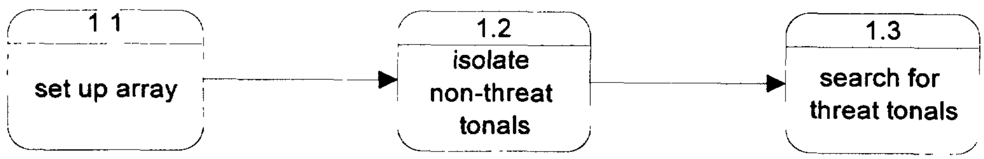
Annex B2 CANTASS Function Flow Diagrams

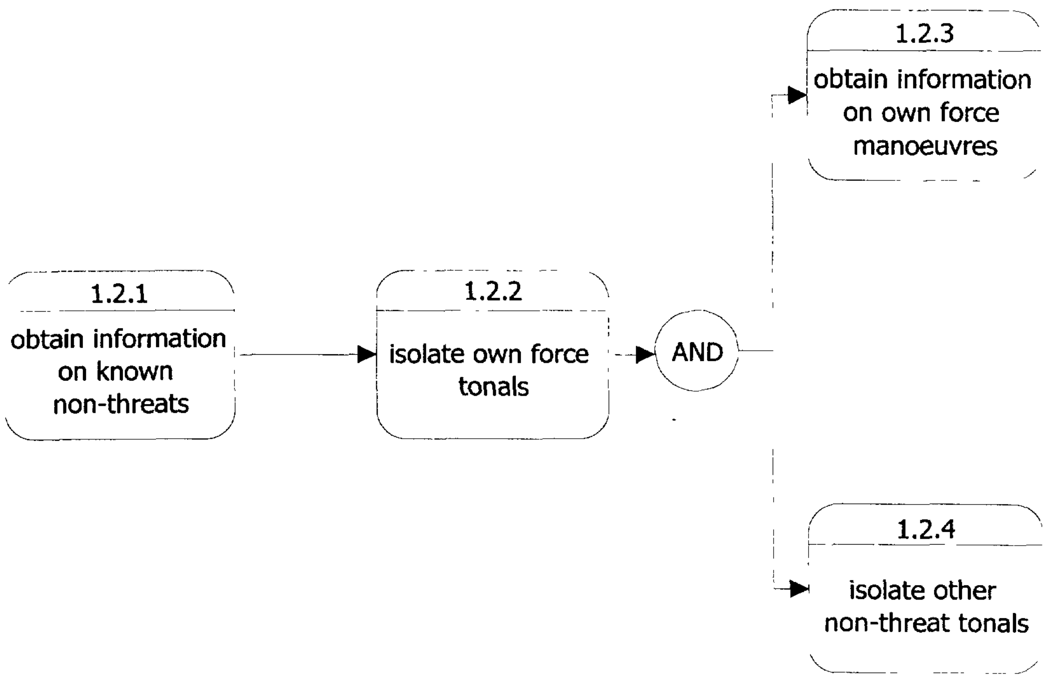
Notes:

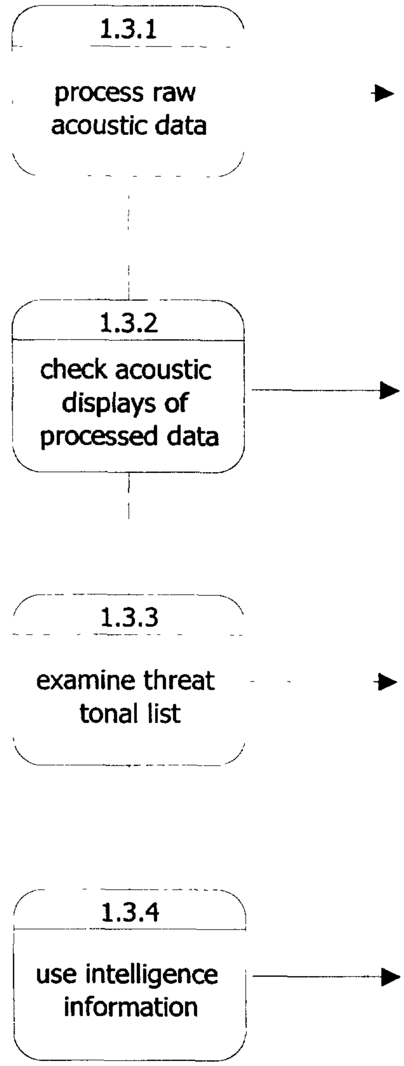
1. New functions are shown in magenta, re-organised or modified YARD functions in cyan.
2. Yellow highlighted text in the function descriptions represent areas of uncertainty.
3. The sub-functions under *3.2 Detect Torpedo Launch* have not been renumbered from the original YARD at this stage. These were originally second level functions and would become third level functions under 3.2.

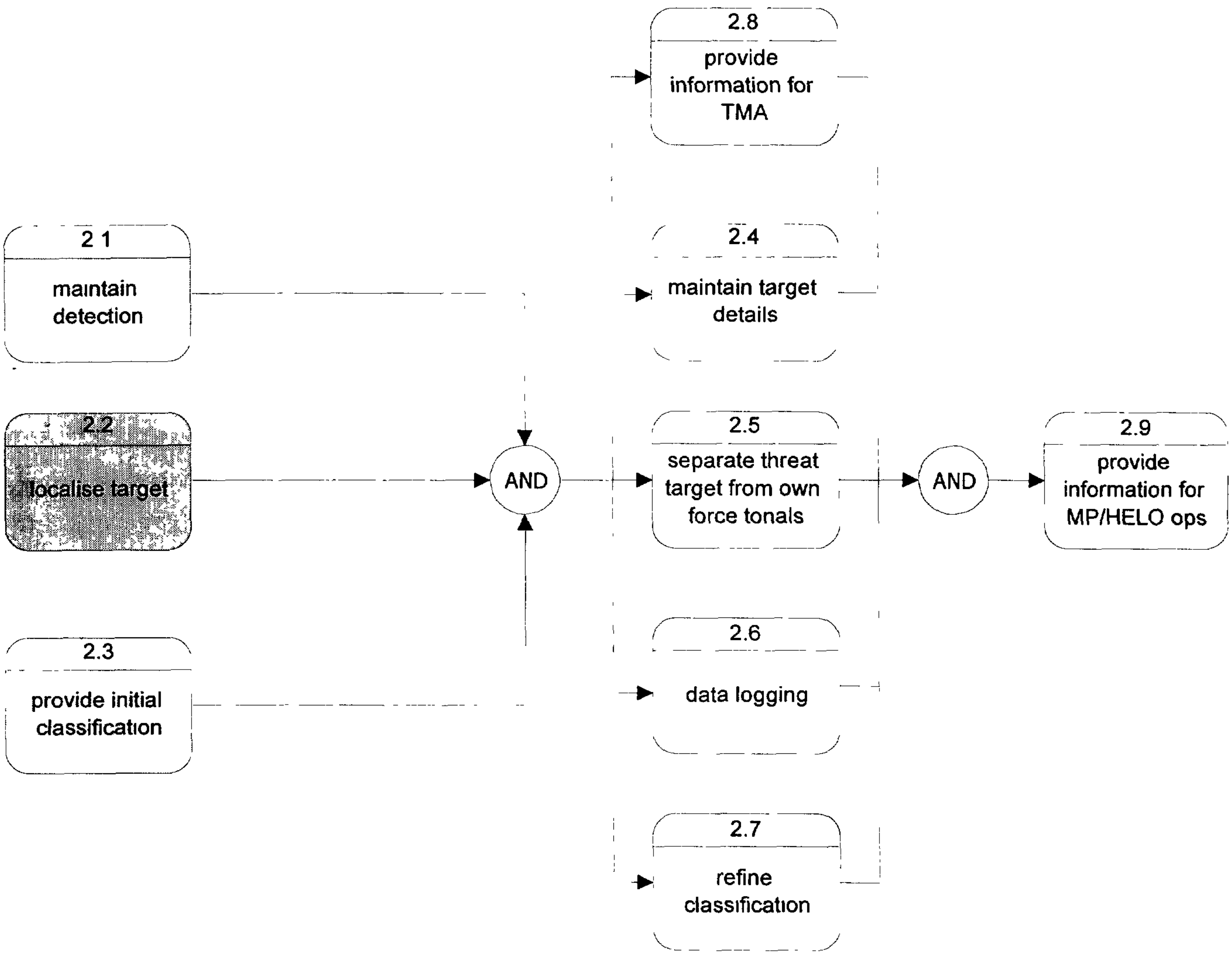

1
Search and Detection
2
Classification and localization
3
Attack/ Prosecution
4
support surface picture
5
prepare oceanographic brief for CO


1.1.1a
receive and process environmental informatio
1.1.1b
receive and process intelligence informatio
AND
1.1.2
advise on scope and depth of
AND
1.1.3
set array receiver parameter
1.1.4
set signal processing parameter
1.1.5
set track processing parameter
1.1.6
set system parameter

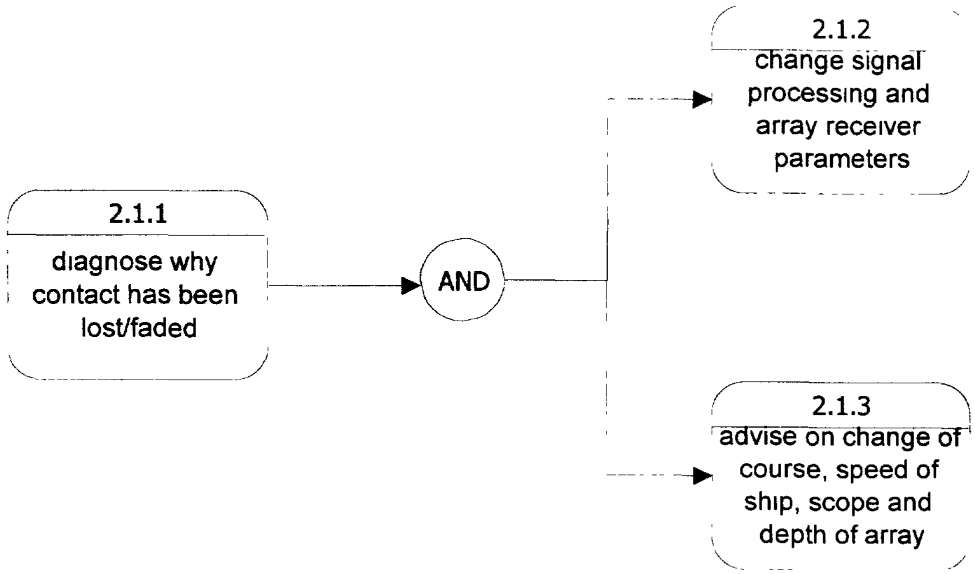

1 1
set up array
1.2
isolate non-threat tonals
1.3
search for threat tonals

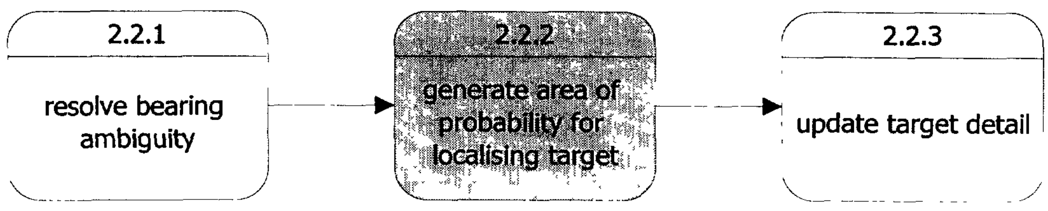

1.2.1
obtain information on known non-threats
1.2.2
isolate own force tonals
AND
1.2.3
obtain information on own force manoeuvres
1.2.4
isolate other non-threat tonals

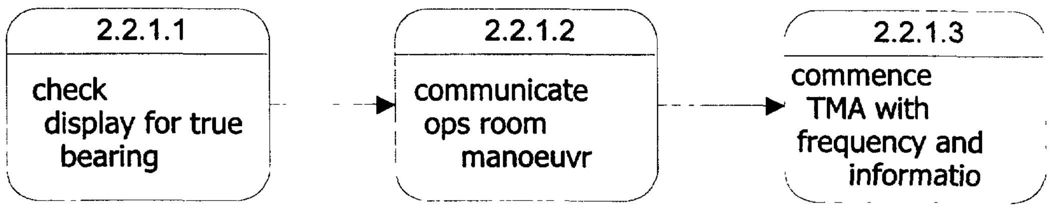

1.3.1
process raw acoustic data
1.3.2
check acoustic displays of processed data
1.3.3
examine threat tonal list
1.3.4
use intelligence information

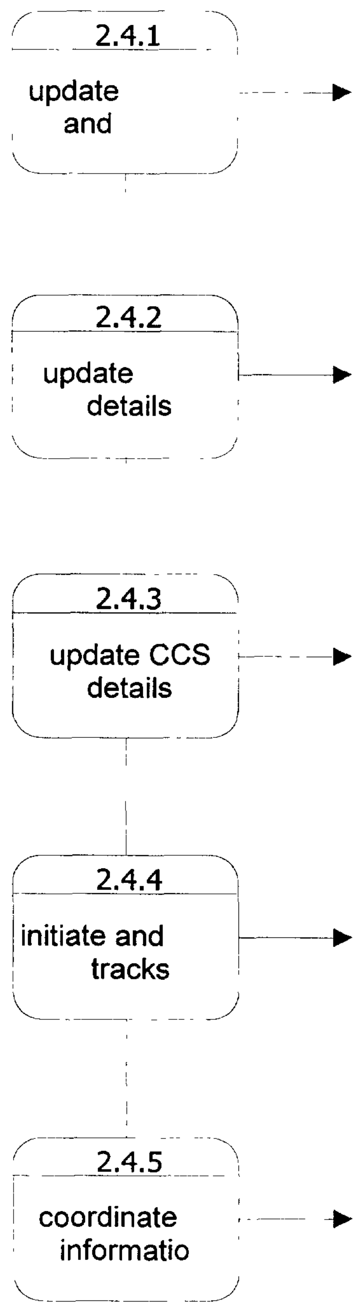


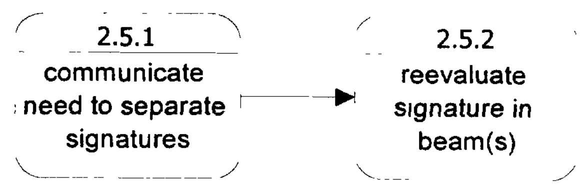
2.1
maintain detection
2.2
localise target
2.3
provide initial classification
AND
2.8
provide information for TMA
2.4
maintain target details
2.5
separate threat target from own force tonals
2.6
data logging
2.7
refine classification
AND
2.9
provide information for MP/HELO ops

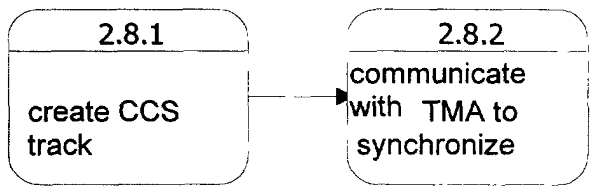

2.1.1
diagnose why contact has been lost/faded
AND
2.1.2
change signal processing and array receiver parameters
2.1.3
advise on change of course, speed of ship, scope and depth of array

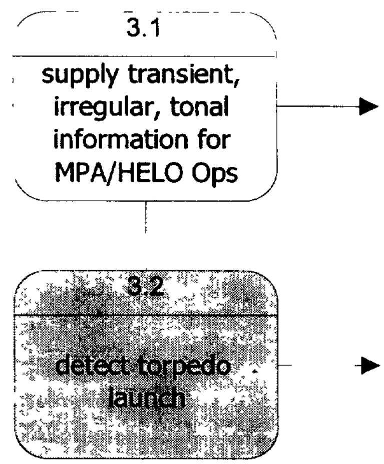

2.2.1
resolve bearing ambiguity
2.2.2
generate area of probability for localising target
2.2.3
update target detail


2.2.1.1
check display for true bearing
2.2.1.2
communicate ops room manoeuvr
2.2.1.3
commence TMA with frequency and informatio

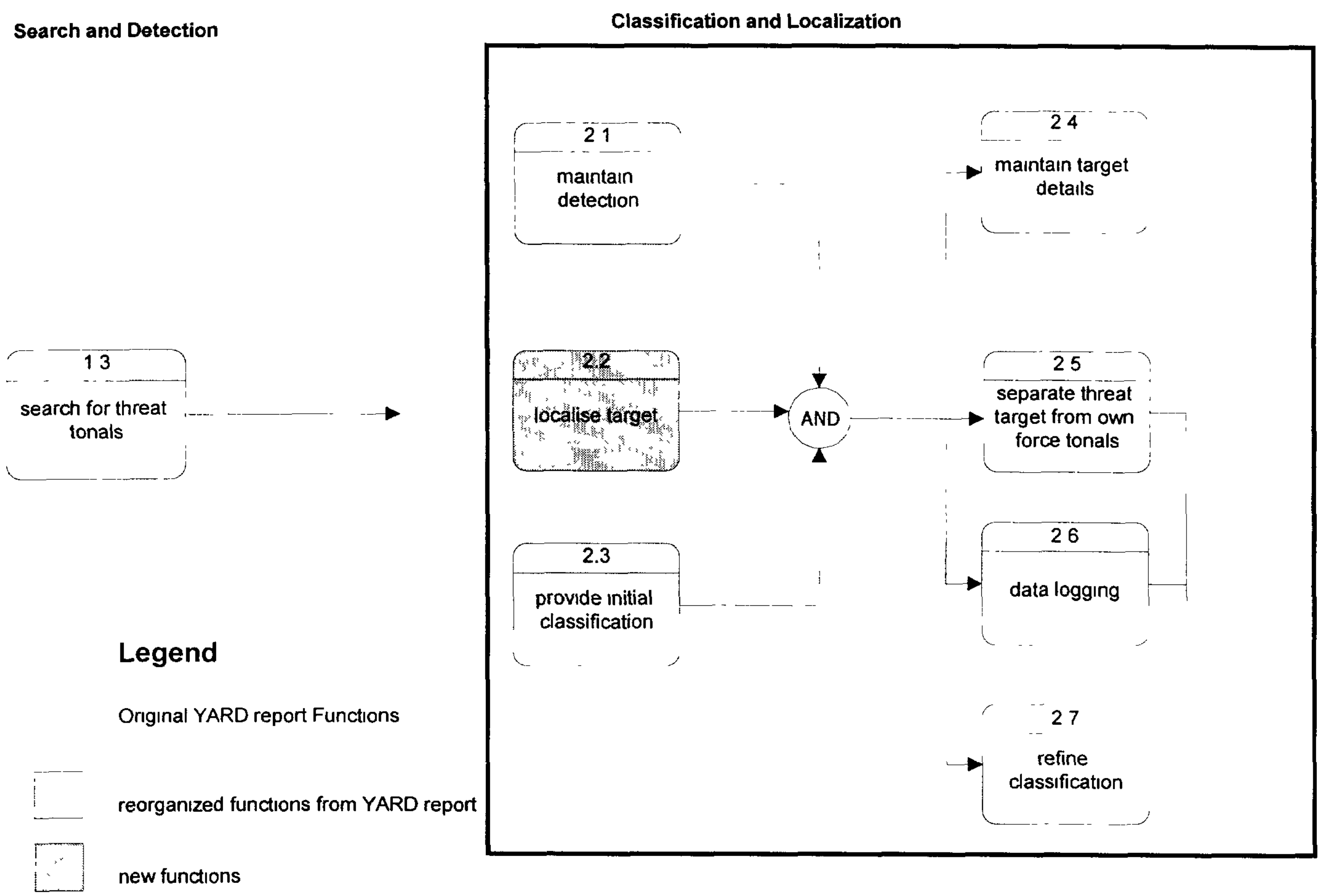

2.4.1
update
and
2.4.2
update
details
2.4.3
update CCS
details
2.4.4
initiate and
tracks
2.4.5
coordinate
informatio


2.5.1
communicate need to separate signatures
2.5.2
reevaluate signature in beam(s)

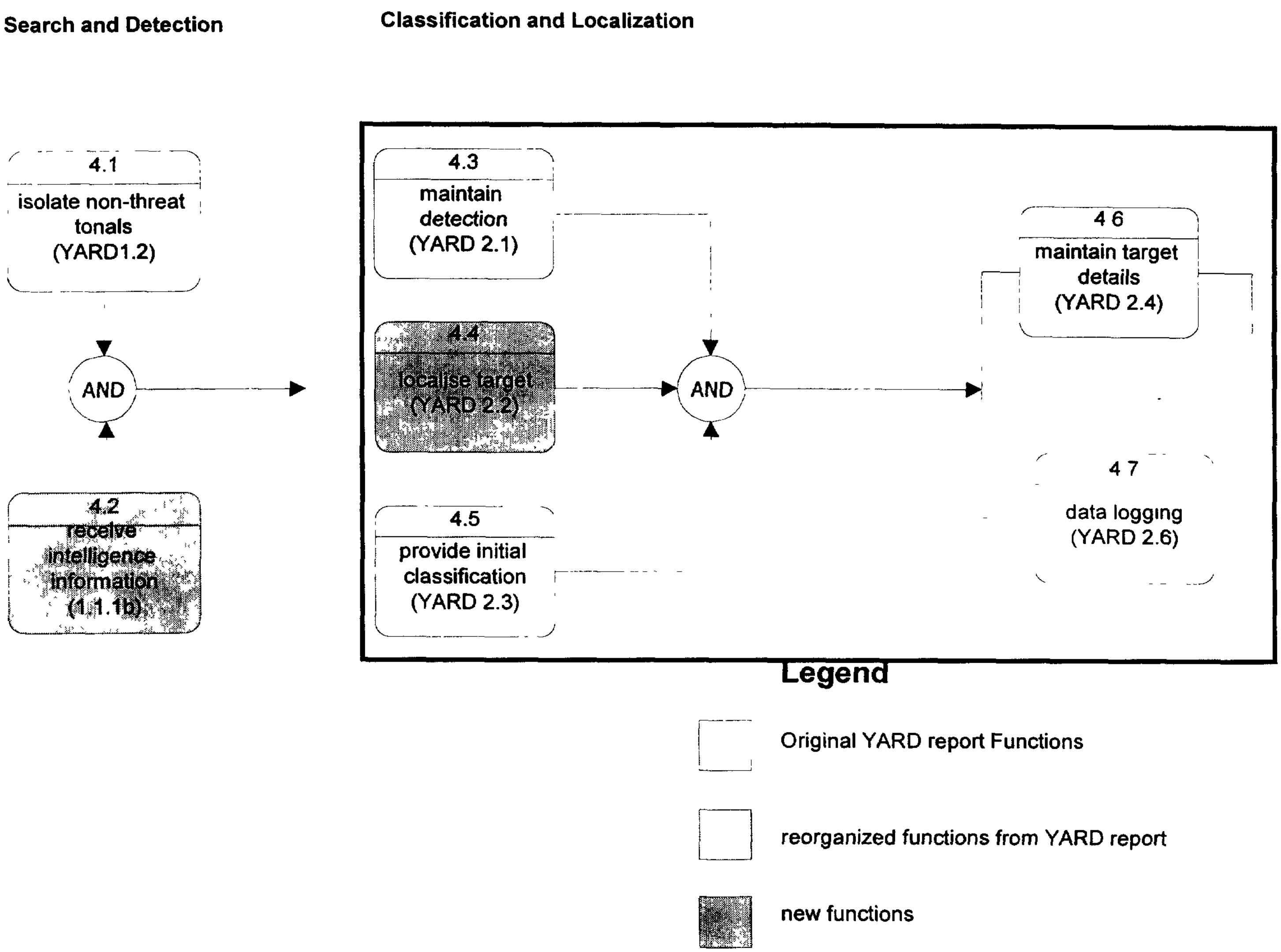

2.8.1
create CCS track
2.8.2
communicate with TMA to synchronize


3.1
supply transient, irregular, tonal information for MPA/HELO Ops
3.2
detect torpedo launch

Detect Torpedo Launch



Support Surface Picture



ANNEX C1:

TIAPS FUNCTION DESCRIPTIONS

Annex C1: TIAPS Function Descriptions

Name of Function
1.0 ANALYSE MISSION

Superordinate Functions
None

Sequential Categorisation of Functions
Discrete

Estimate of Criticality of Function
This function plays a major role in the correct configuration of all the required equipment for a specific mission or operational environment. If equipment is not properly configured, it may either not operate, or operate incorrectly and yield misleading data.

Consequences of Failure to Complete A Function
The TIAPS system cannot be properly operated until this function is performed.

Sub-functions or Tasks
1.1. Receive Information
1.2. Configure workstation
1.3. Configure active sonar
1.4. Configure passive sonar
1.5. Set up required operating mode (fully passive, mostly passive-infrequent pings, regular active schedule)

Sequencing of Sub-functions or Tasks
See flow diagram

Allocation of Function to Man, Software or Hardware
MAN

Interdependency of Functions

Comments
This function represents a critical first step in ensuring that the equipment and environment is appropriately configured based upon information received concerning the mission and the environment. Some of the sub-functions associated with configuring active sonar must be achieved with a high level of accuracy. Since many operational contexts will have elements in common, it is likely that standardised procedural formats and databases of required system settings will be implemented. Some HF issues centre on the appropriate way to configure and present to the operator such standardised settings in a way that will allow this task to be accomplished with speed and accuracy.

Name of Function
1.1 RECEIVE ENVIRONMENTAL INFORMATION

Superordinate Functions
1.0 ANALYSE MISSION

Sequential Categorisation of Functions
Discrete, continuous

Estimate of Criticality of Function
This function plays a major role in the correct configuration of all the required equipment for a specific mission or operational environment. If equipment is not properly configured, it may either not operate, or operate incorrectly and yield misleading data.

Consequences of Failure to Complete A Function
The TIAPS system cannot be properly operated until this function is properly performed.

Sub-functions or Tasks

Sequencing of Sub-functions or Tasks
See flow diagram

Allocation of Function to Man, Software or Hardware
MAN

Interdependency of Functions
1.3 Configure active sonar
1.4 Configure passive sonar
1.5 Set up required operating mode

Comments

Name of Function
1.2 CONFIGURE WORKSTATION

Superordinate Functions
1.0 ANALYSE MISSION

Sequential Categorisation of Functions
Discrete

Estimate of Criticality of Function
This function plays a major role in the correct configuration of all the required equipment for a specific mission or operational environment. This function is necessary to ensure that the workstation is appropriately configured for either the supervisor or operator (or other) position.

Consequences of Failure to Complete A Function
The TIAPS system cannot be properly operated until this function is properly performed.

Sub-functions or Tasks
1.2.1 Configure workstation for mission type
1.2.2 Set local preferences

Sequencing of Sub-functions or Tasks
See flow diagram

Allocation of Function to Man, Software or Hardware
MAN

Interdependency of Functions
1.5 Set up required operating mode

Comments
Each workstation may be configured to assume different functional capabilities depending upon the task to be done and the personnel available. Typically, the workstation will be configured to meet the needs of supervisor tasks or operator tasks.

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Name of Function
1.3 CONFIGURE ACTIVE SONAR

Superordinate Functions
1.0 ANALYSE MISSION

Sequential Categorisation of Functions
Discrete

Estimate of Criticality of Function
This function plays a major role in the correct configuration of the Active Sonar sub-system for a specific mission or operational environment. If this function is performed improperly, unreliable and faulty processed sonar data will be generated.

Consequences of Failure to Complete A Function
The Active sonar sub-system cannot be properly operated until this function is properly performed.

Sub-functions or Tasks
1.3.1 Set waveform
1.3.2 Set wavetrain
1.3.3 Set ping bundle
1.3.4 Set false alarm rate for autodetectors

Sequencing of Sub-functions or Tasks
See flow diagram

Allocation of Function to Man, Software or Hardware
Man, Software

Interdependency of Functions
1.5 Set up required operating mode

Comments
It is expected that this task will be done by selecting the appropriate parameters from a pre-existing database. The operator's task will be to ensure that the selection criteria match the received information describing the mission parameters.

Name of Function
1.4 CONFIGURE PASSIVE SONAR

Superordinate Functions
1.0 ANALYSE MISSION

Sequential Categorisation of Functions
Discrete

Estimate of Criticality of Function
This function plays a major role in the correct configuration of the Passive Sonar sub-system for a specific mission or operational environment. If this function is performed improperly, unreliable and faulty processed sonar data will be generated.

Consequences of Failure to Complete A Function
The passive sonar sub-system cannot be properly operated until this function is properly performed.

Sub-functions or Tasks
1.4.1 Set false alarm rate for autodetectors

Sequencing of Sub-functions or Tasks

Allocation of Function to Man, Software or Hardware
Man, Software

Interdependency of Functions
1.5 Set up required operating mode

Comments
All of the sub-functions associated with configuring passive sonar represent a level of detail that was beyond the model template of the YARD analysis of CANTASS. However, the one particular sub-function identified (nb. it is acknowledged that there are many others) is seen as being of critical importance in a future TIAPS operational implementation. This is because the volume of passive sonar generator generated will be so large that it would be impractical for the operator to analyse it using the current approach in CANTASS. The operator will have to rely more on processes that are "set up and autorun" and whose output will then be monitored. Hence, the configuration of these automated processes to yield a false alarm rate appropriate for the operational environment is a critical task. HF engineering effort will be required to ensure that the task is performed in a highly accurate manner.

Name of Function
1.5 CONFIGURE OPERATING MODE
Note: The operating mode may be fully passive, mostly passive-infrequent pings, regular active schedule.

Superordinate Functions
1.0 ANALYSE MISSION

Sequential Categorisation of Functions
Discrete

Estimate of Criticality of Function
The setting of the operational mode is critical to the achievement of appropriate sonar data for the mission context.

Consequences of Failure to Complete A Function
Neither the active nor the passive sonar sub-system cannot be properly operated unless this function is properly performed.

Sub-functions or Tasks

Sequencing of Sub-functions or Tasks

Allocation of Function to Man, Software or Hardware
Man, Software

Interdependency of Functions

Comments
The specific mode of operation will be determined at the command level and be dictated by operational circumstances. The supervisor's responsibility will be to ensure that the overall sonar system configuration meets command intent.

Name of Function
2.0 CONFIGURE SYSTEM MODEL

Superordinate Functions

Sequential Categorisation of Functions
Continuous

Estimate of Criticality of Function
The creation of the system model is critical to the obtaining appropriate sonar data for the mission context.

Consequences of Failure to Complete A Function
Sonar range may be compromised. Sonar data may be unrepresentative and lead to errors in detection and/or localisation and/or classification.

Sub-functions or Tasks
2.1 Create and maintain environmental model
2.2 Create and maintain sonar model
2.3 Evaluate Model
2.4 Communicate values for sonar analysis

Sequencing of Sub-functions or Tasks
Sub functions are performed sequentially

Allocation of Function to Man, Software or Hardware
Man, Software

Interdependency of Functions

Comments

Name of Function
2.1 CREATE AND MAINTAIN ENVIRONMENTAL MODEL

Superordinate Functions
2.0 CONFIGURE SYSTEM MODEL

Sequential Categorisation of Functions
Continuous

Estimate of Criticality of Function
The creation of the environmental model is critical to the obtaining appropriate sonar data for the mission context.

Consequences of Failure to Complete A Function
Sonar range may be compromised. Sonar data may be unrepresentative and lead to errors in detection and/or localisation and/or classification.

Sub-functions or Tasks
2.1.1 Add current information
2.1.2 Run and refine model (based largely on operator experience)

Sequencing of Sub-functions or Tasks
Sub functions are performed sequentially

Allocation of Function to Man, Software or Hardware
Man, Software

Interdependency of Functions

Comments
The current information to be input includes: sound speed profile, location, sea state.
The refinement of the model is a task that depends heavily on operator experience. Variables include: ambient noise, ownship noise, transmission loss, time frequency and spatial spreading, bottom loss and reverberation.

Name of Function
2.2 CREATE AND MAINTAIN SONAR MODEL

Superordinate Functions
2.0 CONFIGURE SYSTEM MODEL

Sequential Categorisation of Functions
Continuous

Estimate of Criticality of Function
The creation of the sonar model is critical to the obtaining appropriate sonar data for the mission context.

Consequences of Failure to Complete A Function
The sonar system will not be optimised in a manner to provide detection of expected threats.

Sub-functions or Tasks
2.2.1 Update threat information
2.2.2 Update environment information
2.2.3 Run model
2.2.4 Array motion

Sequencing of Sub-functions or Tasks
Sub functions are performed sequentially and iteratively

Allocation of Function to Man, Software or Hardware
Man, Software

Interdependency of Functions

Comments

Name of Function
2.3 EVALUATE MODEL

Superordinate Functions
2.0 CONFIGURE SYSTEM MODEL

Sequential Categorisation of Functions
Continuous

Estimate of Criticality of Function

Consequences of Failure to Complete A Function
The sonar system will not be optimised in a manner to provide detection of expected threats.

Sub-functions or Tasks

Sequencing of Sub-functions or Tasks

Allocation of Function to Man, Software or Hardware
Man, Software

Interdependency of Functions
This function is dependent on functions 2.1 and 2.2

Comments

Name of Function
2.4 COMMUNICATE VALUES FOR SONAR ANALYSIS

Superordinate Functions
2.0 CONFIGURE SYSTEM MODEL

Sequential Categorisation of Functions
Discrete

Estimate of Criticality of Function
It is important for proper operation of the sonar system for the parameter values to be communicated accurately and completely.

Consequences of Failure to Complete A Function
The sonar system will not be optimised in a manner to provide detection of expected threats.

Sub-functions or Tasks

Sequencing of Sub-functions or Tasks

Allocation of Function to Man, Software or Hardware
Man, Software

Interdependency of Functions
This function is dependent on functions 2.1, 2.2 and 2.3

Comments
The operator may pass on the model values, or if experience indicates that they may be inappropriate, operator selected values.

Name of Function
3.0 ASSESS SYSTEM

Superordinate Functions

Sequential Categorisation of Functions
Continuous

Estimate of Criticality of Function

Consequences of Failure to Complete A Function
Incomplete and or inaccurate information may be obtained from sonar processing and analysis.

Sub-functions or Tasks
3.1 Assess environment
3.2 Assess Sonar

Sequencing of Sub-functions or Tasks
Sub functions are performed iteratively

Allocation of Function to Man, Software or Hardware
Man, Software

Interdependency of Functions
This function depends upon completion of 2.0 Set up system model

Comments

Name of Function
3.1 ASSESS ENVIRONMENT

Superordinate Functions
3.0 ASSESS SYSTEM

Sequential Categorisation of Functions
Continuous

Estimate of Criticality of Function
This is a core task in ensuring appropriate configuration of sonar and interpretation of data.

Consequences of Failure to Complete A Function
Incomplete and or inaccurate information may be obtained from sonar processing and analysis.

Sub-functions or Tasks

Sequencing of Sub-functions or Tasks

Allocation of Function to Man, Software or Hardware
Man, Software

Interdependency of Functions
This function depends upon completion of 2.0 Set up system model

Comments
This process involves measuring aspects of the environment based upon information from deployable sensors or information gathered from known sources whose interaction with the system model is already established.

Name of Function
3.2 ASSESS SONAR

Superordinate Functions
3.0 ASSESS SYSTEM

Sequential Categorisation of Functions
Continuous

Estimate of Criticality of Function
This is a core task in ensuring appropriate configuration of sonar and interpretation of data.

Consequences of Failure to Complete A Function
Incomplete and or inaccurate information may be obtained from sonar processing and analysis.

Sub-functions or Tasks
3.2.1 Analyse array motion

Sequencing of Sub-functions or Tasks

Allocation of Function to Man, Software or Hardware
Man, Software

Interdependency of Functions
This function depends upon completion of 2.0 Set up system model

Comments

Name of Function
4.0 CREATE AND MANAGE TACTICAL PICTURE

Superordinate Functions

Sequential Categorisation of Functions
Continuous

Estimate of Criticality of Function
This is the core function for achieving system objectives

Consequences of Failure to Complete A Function
Contacts will fail to be detected, identified, classified and tracked with a subsequent impact upon the Common Operational Picture at the command level.

Sub-functions or Tasks
4.1 Receive mission parameters
4.2 Manage TP overlays
4.3 Select and manage DII/COE data
4.4 Manage contacts
4.5 Analyse contact
4.6 Manage Tracks
4.7 Analyse tactical picture
4.8 Refine configuration of automated processes

Sequencing of Sub-functions or Tasks
Sub functions are performed continuously and iteratively

Allocation of Function to Man, Software or Hardware
Man, Software

Interdependency of Functions
This function depends upon completion of 2.0 Set up system model and 3.0 Assess system

Comments
This function represents a major departure from functions performed in CANTASS or active sonar. The tactical picture provides relevant information passed down from command level. A number of overlays are selectable within the TP, as are appropriate data from DII/COE. The TP provides a high level environment for managing tracks and contacts. Information created within the TP at the TIAPS level may be subsequent made available at the command level. It is possible that the primary user of the TP will be the sonar supervisor who will switch between this view and lower level functions in order to establish what elements of the sonar picture are "real" and what are false alarms or artefacts created by semi-autonomous functions such as autotrackers and track managers.

Name of Function
4.1 RECEIVE MISSION PARAMETERS

Superordinate Functions
4.0 CREATE AND MANAGE TACTICAL PICTURE

Sequential Categorisation of Functions
Continuous

Estimate of Criticality of Function
Accurate mission parameters are required in order to properly configure the workstation and establish the focus for tasks of detection and classification.

Consequences of Failure to Complete A Function
Contacts will fail to be detected, identified, classified and tracked with a subsequent impact upon the Common Operational Picture at the command level.

Sub-functions or Tasks

Sequencing of Sub-functions or Tasks

Allocation of Function to Man, Software or Hardware
Man, Software

Interdependency of Functions
This function depends upon completion of 2.0 Set up system model and 3.0 Assess system

Comments
Information made available concerning mission parameters includes PIMS, threats, counter-detection ranges –active and passive.

Name of Function
4.2 MANAGE TP OVERLAYS

Superordinate Functions
4.0 CREATE AND MANAGE TACTICAL PICTURE

Sequential Categorisation of Functions
Continuous

Estimate of Criticality of Function
While this is not a critical function, poor management of overlays could lead to display clutter and/or display of inappropriate contextual information to support tasks of detection, classification and tracking.

Consequences of Failure to Complete A Function
Contacts will fail to be detected, identified, classified and tracked with a subsequent impact upon the Common Operational Picture at the command level.

Sub-functions or Tasks

Sequencing of Sub-functions or Tasks

Allocation of Function to Man, Software or Hardware
Man, Software

Interdependency of Functions

Comments
This task is important to ensure that the TP contains the appropriate amount of relevant overlay data and irrelevant data are not displayed.

Name of Function
4.3 MANAGE DII/COE DATA

Superordinate Functions
4.0 CREATE AND MANAGE TACTICAL PICTURE

Sequential Categorisation of Functions
Continuous

Estimate of Criticality of Function
While this is not a critical function, poor management of DII/COE data could lead to display clutter and/or display of inappropriate contextual information to support tasks of detection, classification and tracking.

Consequences of Failure to Complete A Function
Contacts will fail to be detected, identified, classified and tracked with a subsequent impact upon the Common Operational Picture at the command level.

Sub-functions or Tasks

Sequencing of Sub-functions or Tasks

Allocation of Function to Man, Software or Hardware
Man, Software

Interdependency of Functions

Comments

Name of Function
4.4 MANAGE CONTACTS

Superordinate Functions
4.0 CREATE AND MANAGE TACTICAL PICTURE

Sequential Categorisation of Functions
Continuous

Estimate of Criticality of Function
Depending on settings for auto-detectors and trackers, there could be a large number of contacts on the tactical display. Failure to disambiguate threat from non-threat and "noise" contacts, and to reduce display clutter from a large number of contacts, will lead to an inaccurate TP with consequences for subsequent ability to detect new contacts and manage tracks.

Consequences of Failure to Complete A Function
Contacts will fail to be detected, identified, classified and tracked with a subsequent impact upon the Common Operational Picture at the command level.

Sub-functions or Tasks
4.4.1 Reduce contact clutter
4.4.2 Identify non-threat contacts
4.4.3 Identify unknown contacts
4.4.4 Determine priority
4.4.5 Associate/ correlate contact

Sequencing of Sub-functions or Tasks

Allocation of Function to Man, Software or Hardware
Man, Software

Interdependency of Functions

Comments
Performance of this function could be degraded in Littoral waters where there is significant potential for large numbers of contacts to be detected by sensors. This function will represent a new task for sonar operators and there remains a number of outstanding questions concerning how this task will be done, what tools will be required to support it and how the task will be time-shared with other tasks that are performed in sub-functions to analyse contact data.

Name of Function
4.4.1 REDUCE CONTACT CLUTTER

Superordinate Functions
4.4 MANAGE CONTACTS

Sequential Categorisation of Functions
Continuous

Estimate of Criticality of Function
Depending on settings for auto-detectors and trackers, there could be a large number of contacts on the tactical display. Failure to disambiguate threat from non-threat and "noise" contacts, and to reduce display clutter from a large number of contacts, will lead to an inaccurate TP with consequences for subsequent ability to detect new contacts and manage tracks.

Consequences of Failure to Complete A Function
Contacts will fail to be detected, identified, classified and tracked with a subsequent impact upon the Common Operational Picture at the command level.

Sub-functions or Tasks

Sequencing of Sub-functions or Tasks

Allocation of Function to Man, Software or Hardware
Man, Software

Interdependency of Functions

Comments
It is possible that one aspect of this function will be to eliminate contacts from own force tonals. It is not known at this stage how much of this process may be automated.

Name of Function
4.4.2. IDENTIFY NON-THREAT CONTACTS

Superordinate Functions
4.4 MANAGE CONTACTS

Sequential Categorisation of Functions
Continuous, concurrent

Estimate of Criticality of Function
These contacts must be quickly eliminated from the tactical display on the basis of an initial classification. The goal is to use appropriate contextual information to ensure that the contact is not confused with a potential threat,

Consequences of Failure to Complete A Function
Too much time could be spent on classification of non-threats and possible threats could be classified as non-threats.

Sub-functions or Tasks

Sequencing of Sub-functions or Tasks

Allocation of Function to Man, Software or Hardware
Man, Software

Interdependency of Functions
This function will be highly dependent upon subordinate functions associated with contact analysis (identification and classification).

Comments

Name of Function
4.4.3. IDENTIFY UNKNOWN CONTACTS

Superordinate Functions
4.4 MANAGE CONTACTS

Sequential Categorisation of Functions
Iterative

Estimate of Criticality of Function
This is a highly critical function. The rapid identification of threats from other contacts is critical for security of the ship or task group.

Consequences of Failure to Complete A Function
The major consequence is failing to detect a signal early enough and hence a hostile sub may penetrate a TG or screen.

Sub-functions or Tasks

Sequencing of Sub-functions or Tasks

Allocation of Function to Man, Software or Hardware
Man, Software

Interdependency of Functions
This function will be highly dependent upon subsequent functions associated with contact analysis (identification and classification).

Comments
The goal in TIAPS is to have semi-autonomous processes monitor the detection of contacts. Hence, the role of the operator will be to monitor the output of these processes.

Name of Function
4.4.4. DETERMINE CONTACT PRIORITY

Superordinate Functions
4.4 MANAGE CONTACTS

Sequential Categorisation of Functions
Iterative

Estimate of Criticality of Function
There is a moderate level of criticality to this function, since if the operator fails to identify the appropriate contacts to analyse first, potential threat contacts will have closed range upon the ship or TG.

Consequences of Failure to Complete A Function
The major consequence is failing to assign the appropriate priority is that a hostile sub may penetrate a TG or screen.

Sub-functions or Tasks

Sequencing of Sub-functions or Tasks

Allocation of Function to Man, Software or Hardware
Man, Software

Interdependency of Functions
This function will be highly dependent upon subsequent functions associated with contact analysis (identification and classification).

Comments
This will be an important task for the operator in Littoral environments or where there is a large number of acoustic sources. Tools will need to be provided to allow the operator to declutter the display and to allow some rapid visual identification of potential highly salient contacts.

Name of Function
4.4.5. ASSOCIATE/CORRELATE CONTACT

Superordinate Functions
4.4 MANAGE CONTACTS

Sequential Categorisation of Functions
Iterative

Estimate of Criticality of Function
There is a moderate level of criticality to this function, since if the operator fails to identify the appropriate contextual information (if any) to associate with the contact unnecessary time may be spent on analysis of sonar data associated with the contact.

Consequences of Failure to Complete A Function
The major consequence is that time will be wasted in analysing the contact.

Sub-functions or Tasks

Sequencing of Sub-functions or Tasks
See associated flow diagram

Allocation of Function to Man, Software or Hardware
Man, Software

Interdependency of Functions

Comments
This will be an important task for the operator; tools will need to be provided to allow the operator to rapidly associate contact data with other tracks or data on the tactical display.

Name of Function
4.5 ANALYSE CONTACT

Superordinate Functions
4.0 CREATE AND MANAGE TACTICAL PICTURE

Sequential Categorisation of Functions
Continuous, concurrent

Estimate of Criticality of Function
Contacts must be quickly eliminated from the tactical display on the basis of an initial classification. The goal is to use appropriate contextual information to ensure that the contact is not confused with a potential threat.

Consequences of Failure to Complete A Function
Too much time could be spent on classification of non-threats and possible threats could be classified as non-threats.

Sub-functions or Tasks
4.5.1 Analyse passive sonar data
4.5.2 Analyse active sonar data

Sequencing of Sub-functions or Tasks
The sequencing of tasks will depend upon the sonar operational mode - active, passive or a mix of the two.

Allocation of Function to Man, Software or Hardware
Man, Software

Interdependency of Functions
This function will be highly dependent upon functions 2.0 Configure system model, 3.0 Assess system and 4.1 Receive mission parameters.

Comments
The analysis of sonar data will be assisted by processes that allow automated detection and tracking of lines of interest.

Name of Function
4.5.1 ANALYSE PASSIVE SONAR DATA

Superordinate Functions
4.5 ANALYSE CONTACT

Sequential Categorisation of Functions
Continuous, concurrent

Estimate of Criticality of Function
This operation is fundamental to passive sonar analysis.

Consequences of Failure to Complete A Function
Failure to complete this function would result in the inability to distinguish threats from non-threats and hence degrade the overall tactical picture to the point where it is unreliable. Sub-function 4.5.1.1 would be greatly impacted as the system would rapidly become populated with unanalysed data.

Sub-functions or Tasks
4.5.1.1 Configure system
4.5.1.2 Search for contacts
4.5.1.3 Classify contact
4.5.1.4 Localise contact

Sequencing of Sub-functions or Tasks
Sub functions are performed concurrently. The search for contacts may occur in parallel with the classification and localisation of other contacts.

Allocation of Function to Man, Software or Hardware
Man, Software

Interdependency of Functions
All functions, with the possible exception of 4.5.2 Analyse active sonar are dependent upon this function.

Comments
The analysis of sonar data will be assisted by processes that allow automated detection and tracking of lines of interest. The tasks involved in the actual analysis process will therefore be somewhat different from those currently performed in CANTASS.

Name of Function
4.5.1.1 CONFIGURE SYSTEM

Superordinate Functions
4.5.1 ANALYSE PASSIVE SONAR DATA

Sequential Categorisation of Functions
Discrete - may be repeated.

Estimate of Criticality of Function
This operation is fundamental to ensuring that automated processes and threat apertures are optimised for the environment, expected threats and tactical situation..

Consequences of Failure to Complete A Function
It is expected that automatic detectors and trackers will assist the contact analysis function. As such, these processes need to be appropriately configured for the situation. Failure to perform this correctly will result in either missed targets or too many false alarms.

Sub-functions or Tasks

Sequencing of Sub-functions or Tasks

Allocation of Function to Man, Software or Hardware
Man, Software

Interdependency of Functions
This function will be highly dependent upon 4.1 Receive mission parameters

Comments
This task is a critical component of ensuring effective operation of automated processors. Some research effort will be required to further understand what is involved in this task and what forms of OMI will be required to allow the function to be performed with the necessary accuracy to generate confidence in the data obtained.

Name of Function
4.5.1.2 SEARCH FOR CONTACTS

Superordinate Functions
4.5.1 ANALYSE PASSIVE SONAR DATA

Sequential Categorisation of Functions
This function is iterative

Estimate of Criticality of Function
This operation is fundamental first step in the analysis of passive data.

Consequences of Failure to Complete A Function
The consequences of failure are that display will start to become cluttered with unanalysed data, the results of which are an inaccurate tactical picture and the possibility of missing threats or detecting them too late for appropriate action.

Sub-functions or Tasks
4.5.1.2.1 Configure signal followers
4.5.1.2.2 Check what computer has merged
4.5.1.2.3 Check what auto process has missed
4.5.1.2.4 Verify contacts that are autodetected
4.5.1.2.5 Select sonar display configuration mode (eg bb/demo)
4.5.1.2.6 Initiate signal followers for weaker signals not auto-detected (note these weaker sigs may not be tracked automatically, likely to be targets of interest)
4.5.1.2.7 Analyse acoustic data
4.5.1.2.8 Analyse non-acoustic data

Sequencing of Sub-functions or Tasks
TBD

Allocation of Function to Man, Software or Hardware
Man, Software

Interdependency of Functions
This function will be highly dependent upon 4.5.1.1 Configure System

Comments
The search for contacts will be a fundamentally different process from that currently performed in CANTASS. The large number of lofargram and other displays precludes the current practice of scrolling though the beams to visually locate potential contacts. Instead, pre-configured autodetectors will perform some initial analysis and display their output possibly in the first instance on the tactical display. Other forms of display may be necessary to summarise this output in a way that allows rapid comprehension in the operator or permits the operator to make decisions on which contacts need to be investigated and analysed further. Research will be needed to understand this task better and to inform OMI design to support the operator's comprehension and decision making.

Name of Function
4.5.1.3 CLASSIFY CONTACT

Superordinate Functions
4.5.1 ANALYSE PASSIVE SONAR DATA

Sequential Categorisation of Functions
This function is continuous over a relatively short period of time and concurrent with 4.5.1.2 Search for contacts.

Estimate of Criticality of Function
This function is highly critical in order to get an early indication of the threat value of the contact.

Consequences of Failure to Complete A Function
Failure to rapidly classify a target may jeopardise the time available for localisation, particularly if the potential threat is close to the vulnerability zone of the task group.

Sub-functions or Tasks
The tasks involved in classification may be somewhat similar to those currently performed in CANTASS. New operator aids in the form of databases of threat profiles, smart cursors and other decision aids are likely to transform the specific tasks involved classification.

Sequencing of Sub-functions or Tasks

Allocation of Function to Man, Software or Hardware
Man, Software

Interdependency of Functions
This function will be highly dependent upon 4.5.1.2 Search for contacts and affects the subsequent function 4.5.1.4 Localise target.

Comments
Some OMI HF development effort will be required to ensure that tools and decision aids for classification are optimised to the operator's needs. Threat libraries, audio data and time history data will be available to assist this task.

Name of Function
4.5.1.4 LOCALISE CONTACT

Superordinate Functions
4.5.1 ANALYSE PASSIVE SONAR DATA

Sequential Categorisation of Functions
This function is continuous over a relatively short period of time and concurrent with 4.5.1.2 Search for contacts and 4.5.1.3 Classify contact.

Estimate of Criticality of Function
This function is highly critical in order to get an early indication of the threat value of the contact and its trajectory with respect to the task group.

Consequences of Failure to Complete A Function
Failure to localise a target will jeopardise the ability to respond to a threat that is close to the vulnerability zone of the task group, or may waste resources in prosecuting a threat that is moving out of the immediate area of interest.

Sub-functions or Tasks
4.5.1.4.1 Manage TMA processor
See also notes under "Comments."

Sequencing of Sub-functions or Tasks

Allocation of Function to Man, Software or Hardware
Man, Software

Interdependency of Functions
This function will be highly dependent upon 4.5.1.2 Search for contacts and 4.5.1.3 Classify contacts and affects the subsequent function 4.6 Manage Tracks.

Comments
While the tasks involved in localisaton may be somewhat similar to those currently performed in CANTASS,, in TIAPS they will differ both in terms of who does them and how they are done. Currently, localisation is a largely manual process conducted by OR team members other than CANTASS operators. TIAPS will provide a capability for some tools adapted from the existing Passive Localisation Assistant (PLA) to directly assist the localisation process. These tools will provide an opportunity for operators to input appropriate contact parameters and to allow visual analysis of the residual error in computed contacted tracks. This should result in a more rapid and accurate projection of target speed and bearing. Research and development effort will be required to support the OMI for these tools. It is further possible that some automated aids for localisation may be able to provide information at the tactical display level to show whether a contact is rapidly moving to or away from the task group, for example in the way a contact is colour and/or blink coded on the screen.

Name of Function
4.5.2 ANALYSE ACTIVE SONAR DATA

Superordinate Functions
4.5.1 ANALYSE CONTACT

Sequential Categorisation of Functions
Continuous, concurrent

Estimate of Criticality of Function
This operation complements the function of passive sonar analysis. In cases where it is not feasible to deploy the array, or the environment or tactical context reduce the reliability and meaningfulness of passive data, then active analysis provides the means for detecting, classifying and possibly localising a contact. The function is critical to operations involving prosecution of a target.

Consequences of Failure to Complete A Function
Failure to complete this function would result in the inability to distinguish threats from non-threats and hence degrade the overall tactical picture to the point where it is unreliable.

Sub-functions or Tasks
4.5.2.1 Check Bathy Information
4.5.2.2 Configure Transmission
4.5.2.3 Configure Receiver
4.5.2.4 Monitor performance/progress of ping schedule
4.5.2.5 Search for contacts
4.5.2.6 Analyse data
4.5.2.7 Classify contact
4.5.2.8 Localise contact

Sequencing of Sub-functions or Tasks
See function flow diagram.

Allocation of Function to Man, Software or Hardware
Man, Software

Interdependency of Functions
All functions, with the possible exception of 4.5.1 Analyse passive sonar are dependent upon this function.

Comments
Until a function analysis is performed of existing hull-mounted and variable depth sonar, it is not possible to comment upon how the active function of TIAPS will differ from existing procedures.

Name of Function
4.5.2.1 CHECK BATHY INFORMATION

Superordinate Functions
4.5.2 ANALYSE ACTIVE SONAR DATA

Sequential Categorisation of Functions
Continuous, concurrent

Estimate of Criticality of Function
This task is important to ensure that the parameters for the transmitter and receiver are appropriately configured as environmental conditions change.

Consequences of Failure to Complete A Function
Failure to complete this function would result in the inability of the active system to produce reliable and meaningful data.

Sub-functions or Tasks

Sequencing of Sub-functions or Tasks

Allocation of Function to Man, Software or Hardware
Man, Software, Hardware

Interdependency of Functions
All functions subsequent active sonar functions are dependent upon this function..

Comments

Name of Function
4.5.2.2 CONFIGURE TRANSMISSION

Superordinate Functions
4.5.2 ANALYSE ACTIVE SONAR DATA

Sequential Categorisation of Functions
Continuous, concurrent

Estimate of Criticality of Function
This task is important to ensure that the transmitter is optimised for the environment and tactical situation.

Consequences of Failure to Complete A Function
Failure to complete this function would result in the inability of the active system to produce reliable and meaningful data.

Sub-functions or Tasks
4.5.2.2.1.1 Set ping sequence
4.5.2.2.1.2 Set Waveform
4.5.2.2.1.3 Set Sector

Sequencing of Sub-functions or Tasks
Sub functions are performed sequentially.

Allocation of Function to Man, Software or Hardware
Man, Software, Hardware

Interdependency of Functions
This function relies on 1.3 Configure Active Sonar, 2.0 Configure Sonar model and 4.5.2.1 Check Bathy Information. Subsequent functions are dependent upon this task being performed accurately.

Comments

Name of Function
4.5.2.3 CONFIGURE RECEIVER

Superordinate Functions
4.5.2 ANALYSE ACTIVE SONAR DATA

Sequential Categorisation of Functions
Continuous, concurrent

Estimate of Criticality of Function
This task is important to ensure that the receiver is optimised for the environment and tactical situation.

Consequences of Failure to Complete A Function
Failure to complete this function would result in the inability of the active system to produce reliable and meaningful data.

Sub-functions or Tasks

4.5.2.3.1	Configure CW
4.5.2.3.2	Configure FM
4.5.2.3.3	Configure ER

Sequencing of Sub-functions or Tasks
Sub functions are perfromed sequentially.

Allocation of Function to Man, Software or Hardware
Man, Software, Hardware

Interdependency of Functions
This function relies on 1.3 Configure Active Sonar, 2.0 Configure sonar model and 4.5.2.1 Check Bathy Information. Subsequent functions are dependent upon this task being performed accurately.

Comments

Name of Function
4.5.2.4 MONITOR PERFORMANCE AND PROGRESS OF PING SCHEDULE

Superordinate Functions
4.5.2 ANALYSE ACTIVE SONAR DATA

Sequential Categorisation of Functions
Continuous, concurrent, iterative.

Estimate of Criticality of Function
This task is important to ensure that the schedule is followed as planned.

Consequences of Failure to Complete A Function
Failure to complete this function could result in the loss of timely information concerning contacts of interest.

Sub-functions or Tasks
4.5.2.4.1 Adjust or change model as required

Sequencing of Sub-functions or Tasks
Sub functions are performed iteratively.

Allocation of Function to Man, Software or Hardware
Man, Software, Hardware

Interdependency of Functions
This function relies on 1.3 Configure Active Sonar, 2.0 Configure sonar model and 4.5.2.1 Check Bathy Information. Subsequent functions are dependent upon this task being performed accurately.

Comments

Name of Function
4.5.2.5 SEARCH FOR CONTACTS

Superordinate Functions
4.5.2 ANALYSE ACTIVE SONAR DATA

Sequential Categorisation of Functions
Continuous, concurrent, iterative.

Estimate of Criticality of Function
This task is fundamental to the task of contact detection.

Consequences of Failure to Complete A Function
Failure to complete this function could result in the loss of timely information concerning contacts of interest.

Sub-functions or Tasks

Sequencing of Sub-functions or Tasks

Allocation of Function to Man, Software or Hardware
Man, Software, Hardware

Interdependency of Functions
This function relies on 1.3 Configure Active Sonar, 2.0 Configure Sonar model and 4.5.2.1 Check Bathy Information, 4.5.2.2 Configure Transmission and 4.5.2.3 Configure Receiver. Subsequent functions are highly dependent upon this task being performed accurately.

Comments
Insufficient information is available at present to determine how this function will be performed in TIAPS.

Name of Function
4.5.2.6 ANALYSE DATA

Superordinate Functions
4.5.2 ANALYSE ACTIVE SONAR DATA

Sequential Categorisation of Functions
Continuous, concurrent, iterative.

Estimate of Criticality of Function
This task is fundamental to the task of determining threats from non-threats as well as for localising and classifying the contact.

Consequences of Failure to Complete A Function
Failure to complete this function could result in the loss of timely information concerning contacts of interest.

Sub-functions or Tasks

Sequencing of Sub-functions or Tasks

Allocation of Function to Man, Software or Hardware
Man, Software, Hardware

Interdependency of Functions
This function relies on 1.3 Configure Active Sonar, 2.0 Configure Sonar Model and 4.5.2.1 Check Bathy Information, 4.5.2.2 Configure Transmission and 4.5.2.3 Configure Receiver. Subsequent functions are highly dependent upon this task being performed accurately.

Comments
Insufficient information is available at present to determine how this function will be performed in TIAPS.

Name of Function
4.5.2.7 CLASSIFY CONTACT

Superordinate Functions
4.5.2 ANALYSE ACTIVE SONAR DATA

Sequential Categorisation of Functions
Continuous, concurrent, iterative.

Estimate of Criticality of Function
This function is highly critical in order to get an early indication of the threat value of the contact.

Consequences of Failure to Complete A Function
Failure to rapidly classify a target may jeopardise the time available for localisation, particularly if the potential threat is close to the vulnerability zone of the task group.

Sub-functions or Tasks

4.5.2.7.1	Extract features
4.5.2.7.2	Reduce clutter
4.5.2.7.3	Analyse non-acoustic data

Sequencing of Sub-functions or Tasks
Sub functions are performed iteratively

Allocation of Function to Man, Software or Hardware
Man, Software, Hardware

Interdependency of Functions
This function relies on 4.5.2.6 Analyse Contact being performed accurately.

Comments
Insufficient information is available at present to determine how this function will be performed in TIAPS.

Name of Function
4.5.2.8 LOCALISE CONTACT

Superordinate Functions
4.5.2 ANALYSE ACTIVE SONAR DATA

Sequential Categorisation of Functions
Continuous, concurrent, iterative.

Estimate of Criticality of Function
This function is highly critical in order to get an early indication of the threat value of the contact.

Consequences of Failure to Complete A Function
Failure to localise a target will jeopardise the ability to respond to a threat that is close to the vulnerability zone of the task group, or may waste resources in prosecuting a threat that is moving out of the immediate area of interest.

Sub-functions or Tasks
4.5.2.8.1 Determine latitude and longitude
4.5.2.8.2 Determine course and speed

Sequencing of Sub-functions or Tasks
Sub functions are performed iteratively and concurrently

Allocation of Function to Man, Software or Hardware
Man, Software, Hardware

Interdependency of Functions
This function relies on 4.5.2.6 Analyse Contact being performed accurately.

Comments
Insufficient information is available at present to determine how this function will be performed in TIAPS.

Name of Function
4.6 MANAGE TRACKS

Superordinate Functions
4.0 CREATE AND MANAGE TACTICAL PICTURE

Sequential Categorisation of Functions
Continuous, concurrent

Estimate of Criticality of Function
This function is important in ensuring that the tactical picture is accurate and uncluttered.

Consequences of Failure to Complete A Function
The tactical display could become rapidly overpopulated with tracks whose presence muddies the tactical picture. If different tracks based upon the same source are not reconciled then a highly misleading tactical picture results.

Sub-functions or Tasks
4.6.1 Maintain track positions
4.6.2 Correlation/associate tracks
4.6.3 Maintain track database
4.6.4 Report tracks

Sequencing of Sub-functions or Tasks
Sub functions may be performed concurrently.

Allocation of Function to Man, Software or Hardware
Man, Software

Interdependency of Functions
This function will be highly dependent upon functions 4.4. Manage Contacts and 4.5 Analyse Contacts

Comments
This represents a potentially new task within the sonar processing team. The tactical picture is a core operational concept that is shared among the sonar analysis team and command levels. Managing this picture at the sonar level will be a critical and challenging task, in order to ensure that command has available a current and accurate picture of contacts detected and identified by the sonar system.

Name of Function
4.6.1 MAINTAIN TRACK POSITIONS

Superordinate Functions
4.6 MANAGE TRACKS

Sequential Categorisation of Functions
Continuous, concurrent

Estimate of Criticality of Function
This function is important in ensuring that the location of tracks is accurate.

Consequences of Failure to Complete A Function
If the track location is incorrect then (1) a potential threat may intrude into the task group vulnerability zone, alternately (2) resources may be misallocated in pursuing a track which is no longer in a threatening location.

Sub-functions or Tasks

Sequencing of Sub-functions or Tasks

Allocation of Function to Man, Software or Hardware
Man, Software

Interdependency of Functions

Comments
Track locations may be posted on the tactical display either from semi-automated processes, such as TMA, or by operator input. The supervisor who is managing the tracks will need to know the source of the information on which track location is based, as well as being able to access a visual representation of the possible error in location.

Name of Function
4.6.2 CORRELATE/ASSOCIATE TRACKS

Superordinate Functions
4.6 MANAGE TRACKS

Sequential Categorisation of Functions
Continuous, concurrent

Estimate of Criticality of Function
This function is important in ensuring that the identity and location of tracks is accurate. The task requires the supervisor to ensure that each track is unique and not a duplicate and conversely to ensure that tracks that have been merged are not separate contacts. This function may also be of involved in the process of associating tracks with sonar data.

Consequences of Failure to Complete A Function
If two tracks from the same contact are not resolved rapidly, unnecessary time and resources may be spent in dealing with each track. Also a failure to associate or correlate tracks may result in extra effort expended in identification and classification functions.

Sub-functions or Tasks

Sequencing of Sub-functions or Tasks

Allocation of Function to Man, Software or Hardware
Man, Software

Interdependency of Functions
Thus function is dependent upon 4.4.5 Contact Correlation/Associate, 4.5.1.3 (and 4.5.2.7) Classify contact and 4.5.1.4 (and 4.5.2.8) Localise contact.

Comments
Research and design effort will be need to create an appropriate tool suite to aid this process.

Name of Function
4.6.3 MAINTAIN TRACK DATABASE

Superordinate Functions
4.6 MANAGE TRACKS

Sequential Categorisation of Functions
Continuous, concurrent

Estimate of Criticality of Function
This function is less critical in the short term, since tracks that are the focus of attention will be displayed on the tactical picture. It is expected that much of the housekeeping associated with mainataining the database will be performed by software. At present this function tends to be put aside and delayed under conditions of heavy workload.

Consequences of Failure to Complete A Function
Failure to update the track database could result in loss of time in identifying and/or processing tracks and misleading information available at the command level.

Sub-functions or Tasks

Sequencing of Sub-functions or Tasks

Allocation of Function to Man, Software or Hardware
Software (monitored by man).

Interdependency of Functions

Comments
Maintenance of the track database is a time consuming, paper and pencil and data entry process in current operations. Successful implementation of track maintenance software will result in a significant saving of operator resources. Design effort will be required to provide the operator with the appropriate tools to monitor the status of the database and to access or modify its contents.

Name of Function
4.6.4 REPORT TRACKS

Superordinate Functions
4.6 MANAGE TRACKS

Sequential Categorisation of Functions
Continuous, concurrent

Estimate of Criticality of Function
The accurate reporting of track information is critical to ensuring that the UW tactical picture at the command level is complete and accurate.

Consequences of Failure to Complete A Function
If this function is not completed, there would be no UW tactical picture available at the command level with consequent serious consequences in the presence of threats.

Sub-functions or Tasks

Sequencing of Sub-functions or Tasks

Allocation of Function to Man, Software or Hardware
Software.

Interdependency of Functions
Depends on 4.6.1. Maintain track positions, 4.6.2 Correlate/Associate tracks and 4.6.3 Maintain track database.

Comments
This is expected to be an automated process under TIAPS. Command level will be able to selectively access the required track information maintained in the tactical picture or track database.

Name of Function
4.7 ANALYSE TACTICAL PICTURE

Superordinate Functions
4.0 CREATE AND MANAGE TACTICAL PICTURE

Sequential Categorisation of Functions
Continuous, concurrent

Estimate of Criticality of Function
This function is important in ensuring that the implications of the information in the tactical picture are interpreted in a tactical context.

Consequences of Failure to Complete A Function
The tactical significance of UW information is critical for accurate command decision making.

Sub-functions or Tasks
4.7.1 Determine contact threat level
4.7.2 Ensure all tracks accounted for
4.7.3 Delete contacts as required

Sequencing of Sub-functions or Tasks
Sub functions may be performed concurrently.

Allocation of Function to Man, Software or Hardware
Man, Software

Interdependency of Functions
This function will be highly dependent upon functions 4.4. Manage Contacts and 4.5 Analyse Contacts

Comments
This represents a potentially new task within the sonar processing team. The tactical picture is a core operational concept that is shared among the sonar analysis team and command levels. Analysis of this picture at the sonar level will be a critical and challenging task, in order to ensure that command has available a current and accurate picture of contacts detected and identified by the sonar system. At present, it is not possible to determine whether this function will be performed at the sonar team level or above.

Name of Function
4.7.1 DETERMINE CONTACT THREAT LEVEL

Superordinate Functions
4.7 ANALYSE TACTICAL PICTURE

Sequential Categorisation of Functions
Continuous, concurrent

Estimate of Criticality of Function
This function is important in ensuring that contacts are analysed in a serial manner according to their threat priority.

Consequences of Failure to Complete A Function
Time would be wasted in analysing low priority contacts with the consequence of leaving insufficient time to analyse and react to threat contacts.

Sub-functions or Tasks

Sequencing of Sub-functions or Tasks

Allocation of Function to Man, Software or Hardware
Man, Software

Interdependency of Functions
This function will be highly dependent upon functions 4.4. Manage Contacts and 4.5 Analyse Contacts

Comments
The goal in TIAPS is to provide visual coding cues to contact threat priority on the tactical display.

Name of Function
4.7.2 ENSURE ALL TRACKS ACCOUNTED FOR

Superordinate Functions
4.7 ANALYSE TACTICAL PICTURE

Sequential Categorisation of Functions
Continuous, concurrent

Estimate of Criticality of Function
This function is important in ensuring that no contacts are overlooked and have been appropriately analysed.

Consequences of Failure to Complete A Function
A failure to observe and analyse a track could result in a hostile threat approaching the TG or screen to a point where the appropriate response could not be implemented in time.

Sub-functions or Tasks

Sequencing of Sub-functions or Tasks

Allocation of Function to Man, Software or Hardware
Man, Software

Interdependency of Functions
This function will be highly dependent upon functions 4.4. Manage Contacts and 4.5 Analyse Contacts

Comments

Name of Function
4.7.3 DELETE CONTACTS AS REQUIRED

Superordinate Functions
4.7 ANALYSE TACTICAL PICTURE

Sequential Categorisation of Functions
Continuous, concurrent

Estimate of Criticality of Function
While less critical than other functions, failure to perform it will degrade the performance of functions such as 4.5.1.2 Search for Contacts.

Consequences of Failure to Complete A Function
The display could become cluttered with unreliable or tactically irrelevant tracks

Sub-functions or Tasks

Sequencing of Sub-functions or Tasks

Allocation of Function to Man, Software or Hardware
Man, Software

Interdependency of Functions
This function will be highly dependent upon functions 4.4. Manage Contacts and 4.5 Analyse Contacts

Comments
The goal in TIAPS is to provide visual coding cues to contact threat priority on the tactical display.

Name of Function
4.8 REFINE CONFIGURATION OF AUTOMATED PROECESSES

Superordinate Functions
4.0 CREATE AND MANAGE TACTICAL PICTURE

Sequential Categorisation of Functions
Continuous, concurrent

Estimate of Criticality of Function
This function is important in ensuring that automated processes provide accurate and reliable information.

Consequences of Failure to Complete A Function
The failure to perform this task could mean that time would be wasted in analysing auto-detected contacts that were due to noise sources, or, more importantly threat contacts may fail to be detected.

Sub-functions or Tasks
4.8.1 Evaluate Performance of Automated Processes
4.8.2 Adjust parameters of Automated Processes

Sequencing of Sub-functions or Tasks
Sub functions may be performed concurrently.

Allocation of Function to Man, Software or Hardware
Man, Software

Interdependency of Functions
This function will be highly dependent upon functions 3.0 Assess system and 4.5 Analyse Contact

Comments
Failure to recognise that an automated process is providing inaccurate or incomplete information represents a problem for tactical picture compilation. This task will demand operator attention and workload when operations are conducted in littoral environments.

Name of Function
4.8.1 EVALUATE PERFORMANCE OF AUTOMATED PROECESSES

Superordinate Functions
4.0 CREATE AND MANAGE TACTICAL PICTURE

Sequential Categorisation of Functions
Continuous, concurrent

Estimate of Criticality of Function
This function is important in ensuring that automated processes provide accurate and reliable information.

Consequences of Failure to Complete A Function
The failure to perform this task could mean that time would be wasted in analysing auto-detected contacts that were due to noise sources, or, more importantly threat contacts may fail to be detected.

Sub-functions or Tasks

Sequencing of Sub-functions or Tasks
Sub functions may be performed concurrently.

Allocation of Function to Man, Software or Hardware
Man, Software

Interdependency of Functions

Comments
In order for this to be a manageable task from a time and workload perspective, tools will need to be provided to allow operators to assess readily the performance of the automated process.

Name of Function
4.8.2 ADJUST PARAMETERS OF AUTOMATED PROECESSES

Superordinate Functions
4.0 CREATE AND MANAGE TACTICAL PICTURE

Sequential Categorisation of Functions
Continuous, concurrent

Estimate of Criticality of Function
This function is important in ensuring that automated processes provide accurate and reliable information.

Consequences of Failure to Complete A Function
The failure to perform this task could mean that time would be wasted in analysing auto-detected contacts that were due to noise sources, or, more importantly threat contacts may fail to be detected.

Sub-functions or Tasks

Sequencing of Sub-functions or Tasks
Sub functions may be performed concurrently.

Allocation of Function to Man, Software or Hardware
Man, Software

Interdependency of Functions

Comments
Tools will need to be provided to allow operators to assess readily the consequences of adjusting parameters upon the performance of the automated process.

Name of Function
5.0 RECORD AND ANALYSE DATA

Superordinate Functions
None

Sequential Categorisation of Functions
Continuous, Concurrent

Estimate of Criticality of Function
TBD

Consequences of Failure to Complete A Function
TBD

Sub-functions or Tasks

Sequencing of Sub-functions or Tasks

Allocation of Function to Man, Software or Hardware
MAN/Software

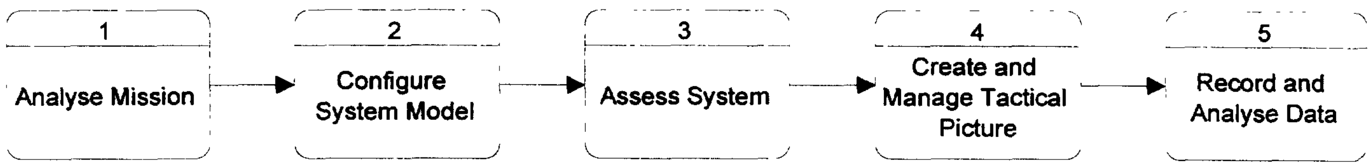
Interdependency of Functions

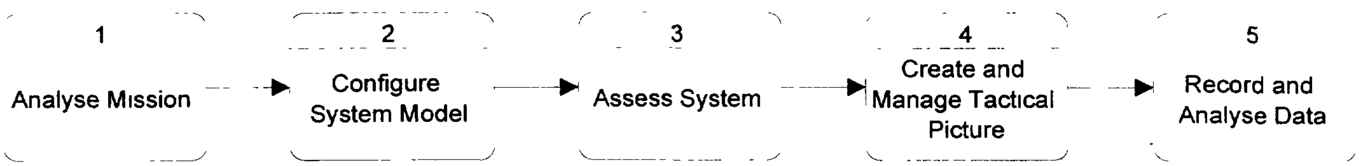
Comments
This function represents a capability in the TIAPS system to record, report, playback and plot specified time ordered data from tape. Since the data plotter will have the capability of generating 2D and 3D graphical plots of numerical data, some HF research and development may be required to optimise the OMI. Further, some consideration should be given to developing test and evaluation requirements for data recording so that selected data attributes and operator actions and responses may be recorded in a format that will allow the creation of some basic measures of performance (MOPs).

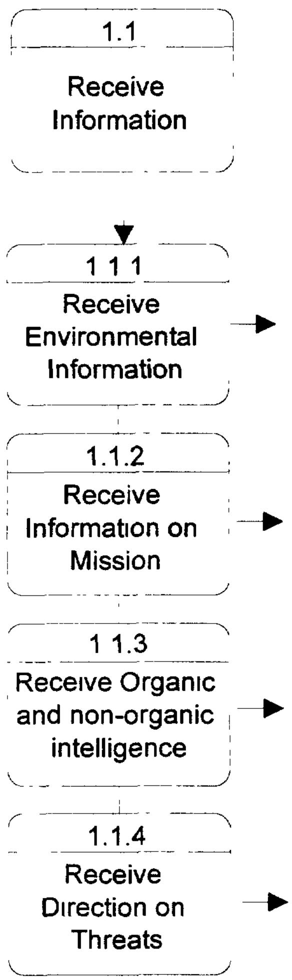
ANNEX C2:

TIAPS FUNCTION FLOW DIAGRAMS

Annex C2: TIAPS Function Flow Diagrams




1
Analyse Mission
2
Configure System Model
3
Assess System
4
Create and Manage Tactical Picture
5
Record and Analyse Data


1.1
Receive Information
1 1 1
Receive Environmental Information
1.1.2
Receive Information on Mission
1 1.3
Receive Organic and non-organic intelligence
1.1.4
Receive Direction on Threats

1.2

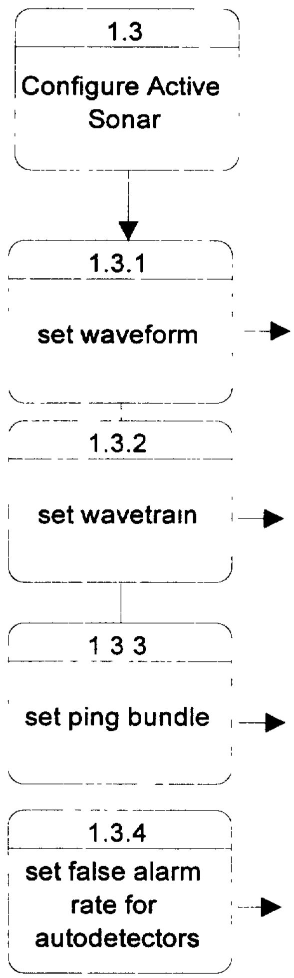
Configure Workstation

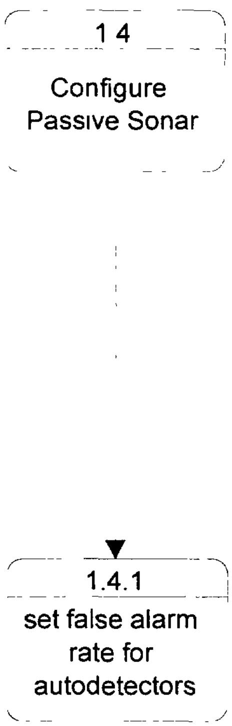
1.2.1

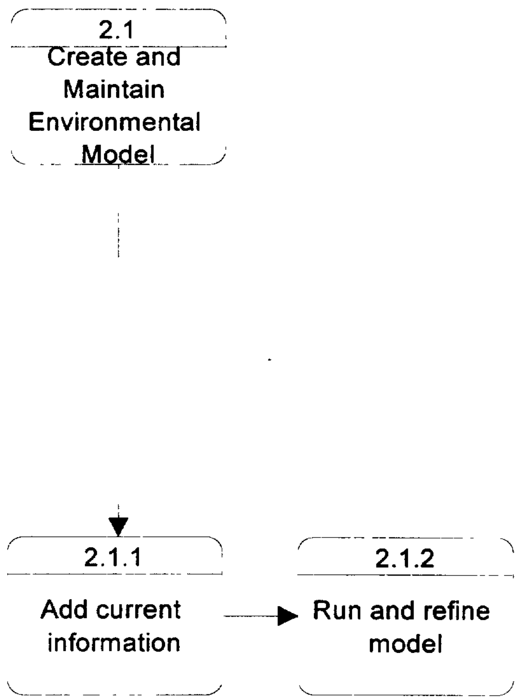
setup for mission type

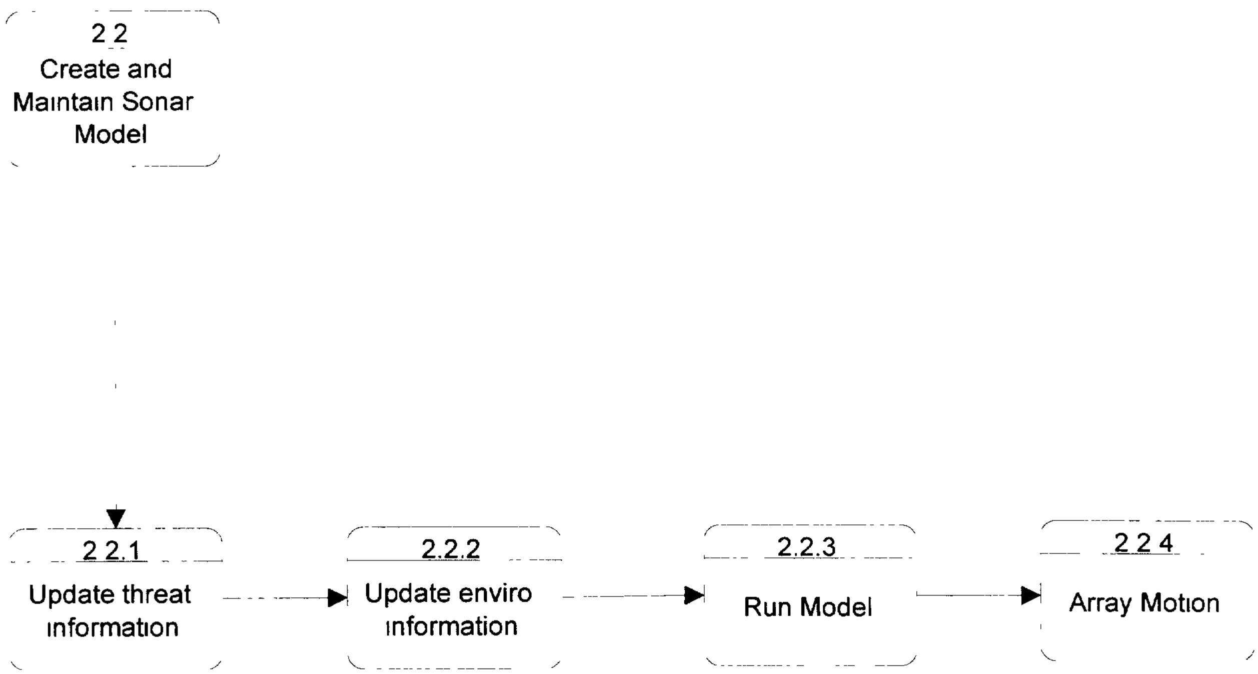
1 2 2

set local preferences

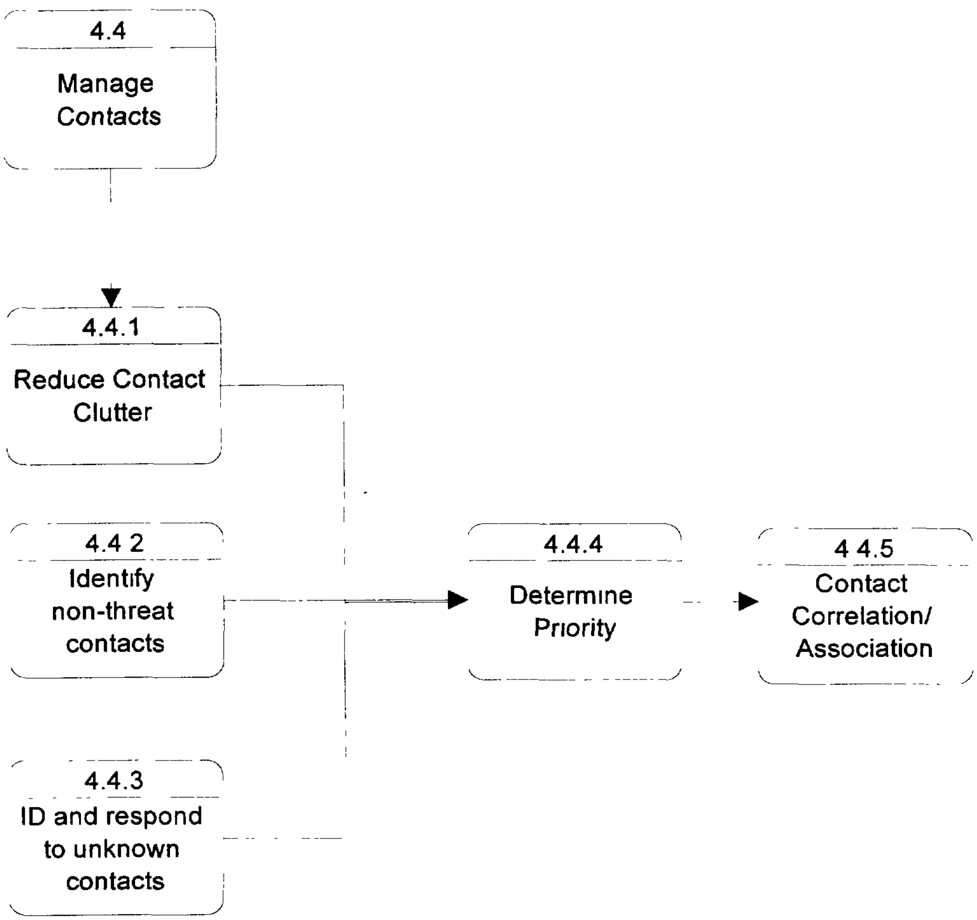

1.3
Configure Active Sonar
1.3.1
set waveform
1.3.2
set wavetrain
1 3 3
set ping bundle
1.3.4
set false alarm rate for autodetectors

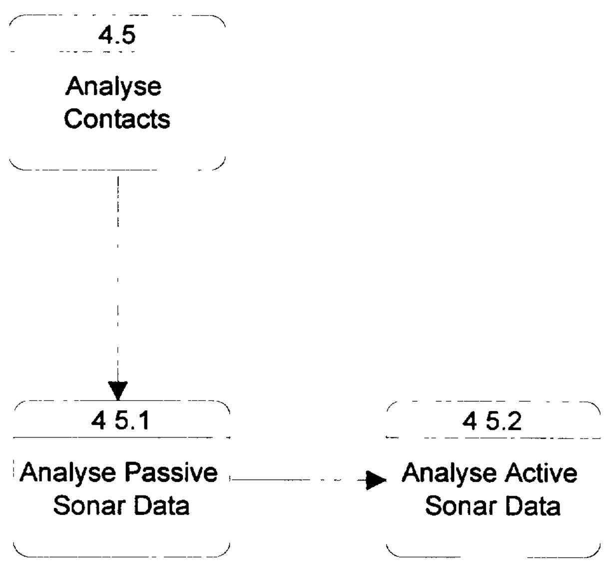

1 4
Configure Passive Sonar
1.4.1
set false alarm rate for autodetectors

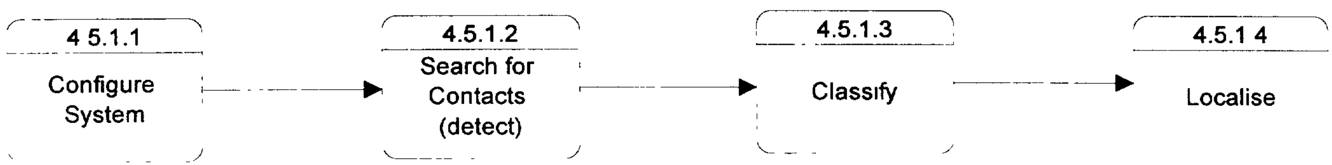

2.1
Create and Maintain Environmental Model
2.1.1
Add current information
2.1.2
Run and refine model

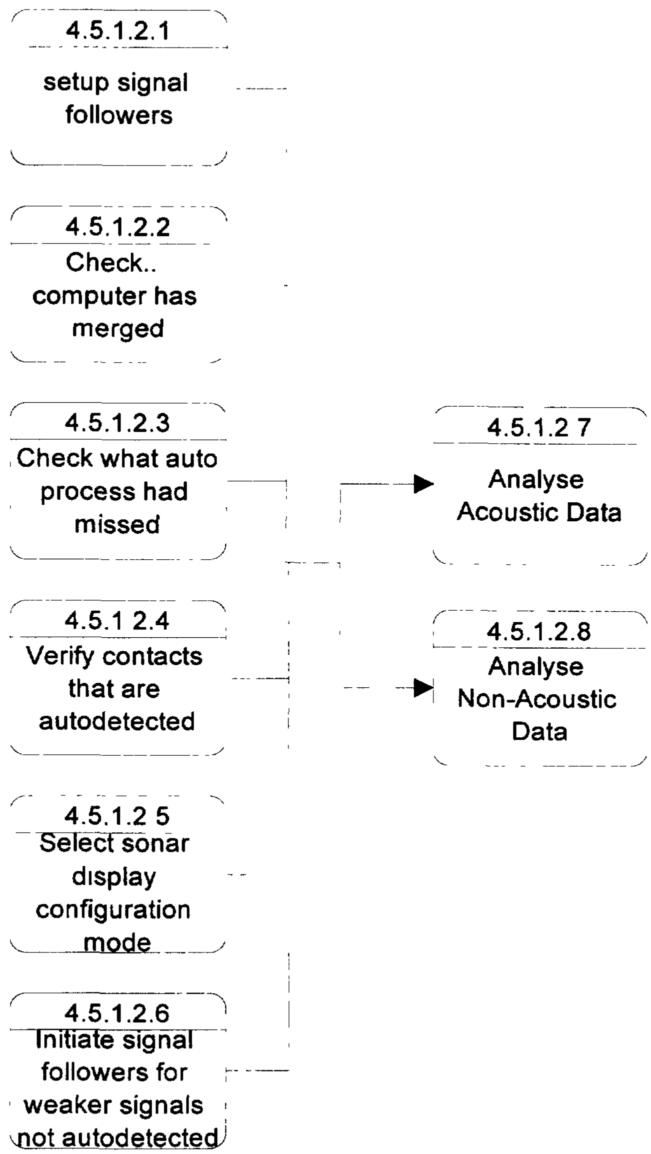

2.2
Create and Maintain Sonar Model
2.2.1
Update threat information
2.2.2
Update enviro information
2.2.3
Run Model
2.2.4
Array Motion

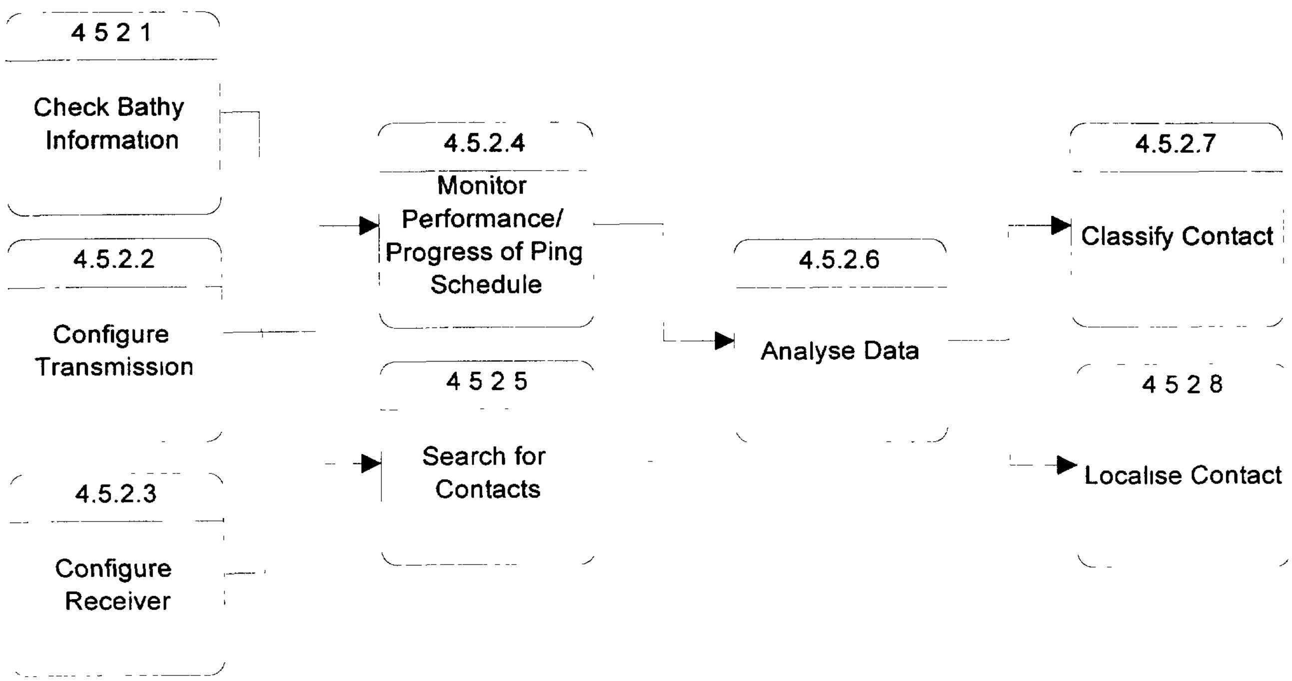

3 2
Assess Sonar
3.2.1
Analyse Array
Motion


4.4
Manage Contacts
4.4.1
Reduce Contact Clutter
4.4 2
Identify non-threat contacts
4.4.3
ID and respond to unknown contacts
4.4.4
Determine Priority
4 4.5
Contact Correlation/ Association


4.5
Analyse Contacts
4 5.1
Analyse Passive Sonar Data
4 5.2
Analyse Active Sonar Data


4 5.1.1
Configure System
4.5.1.2
Search for Contacts (detect)
4.5.1.3
Classify
4.5.1 4
Localise


4.5.1.2.1
setup signal followers
4.5.1.2.2
Check.. computer has merged
4.5.1.2.3
Check what auto process had missed
4.5.1 2.4
Verify contacts that are autodetected
4.5.1.2 5
Select sonar display configuration mode
4.5.1.2.6
Initiate signal followers for weaker signals not autodetected
4.5.1.2 7
Analyse Acoustic Data
4.5.1.2.8
Analyse Non-Acoustic Data


4 5 2 1
Check Bathy Information
4.5.2.2
Configure Transmission
4.5.2.3
Configure Receiver
4.5.2.4
Monitor Performance/ Progress of Ping Schedule
4 5 2 5
Search for Contacts
4.5.2.6
Analyse Data
4.5.2.7
Classify Contact
4 5 2 8
Localise Contact

4.5 2.2 1

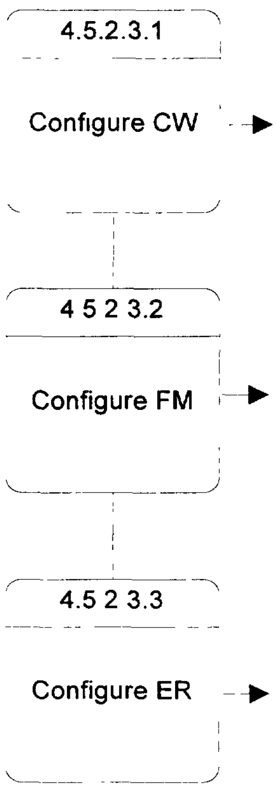
Setup Ping Sequence

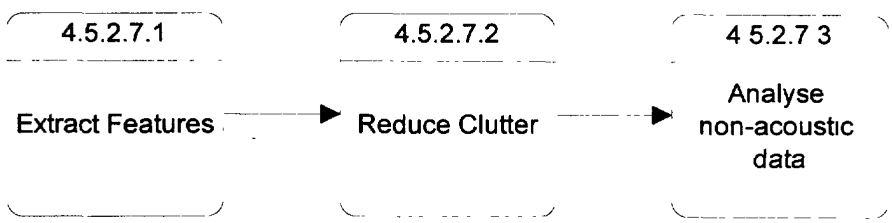
4.5.2.2.2

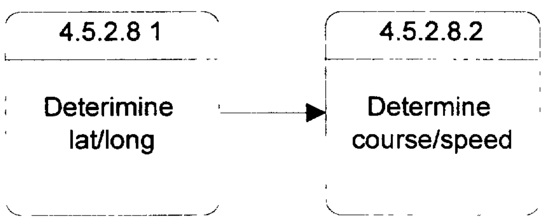
Setup Waveform

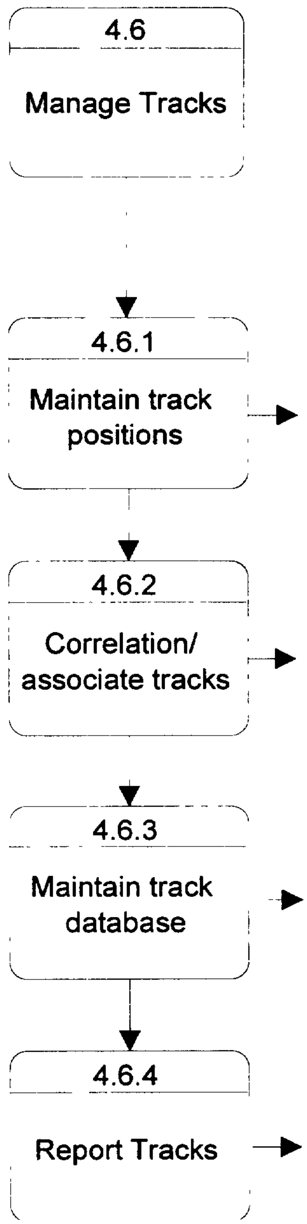
4.5.2.2.3

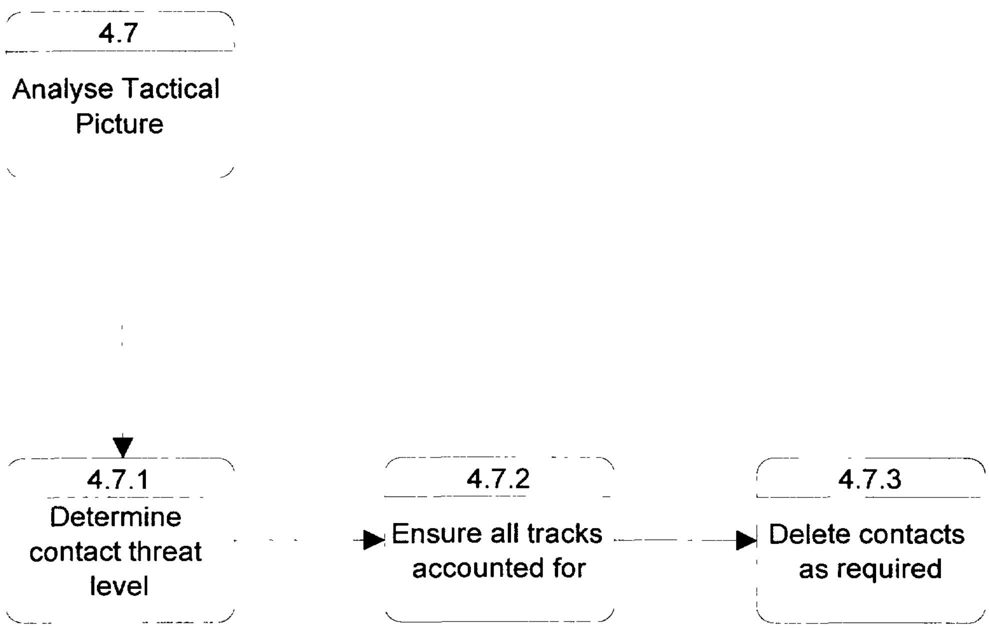
Setup Sequence

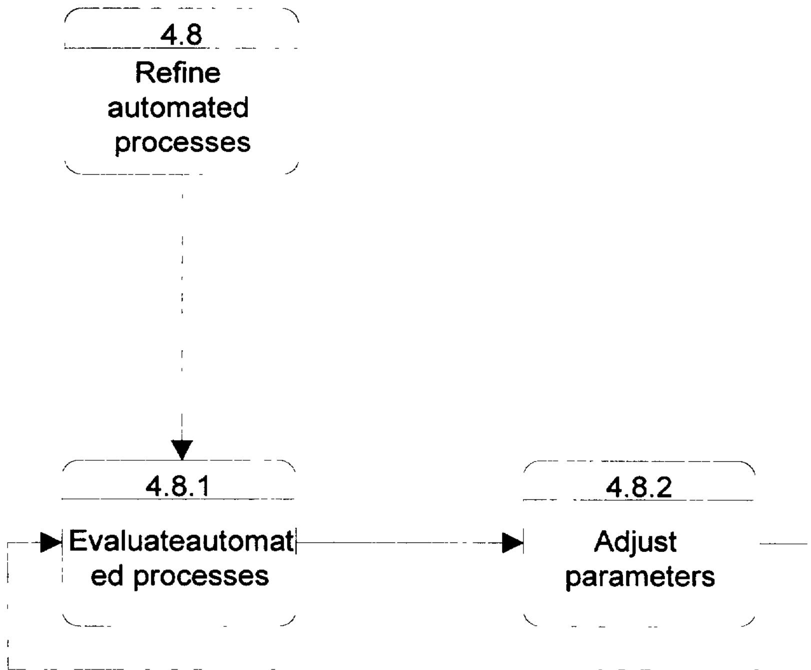

4.5.2.3.1
Configure CW
4 5 2 3.2
Configure FM
4.5 2 3.3
Configure ER


4.5.2.7.1
Extract Features
4.5.2.7.2
Reduce Clutter
4 5.2.7 3
Analyse
non-acoustic
data


4.5.2.8 1
Deterimine lat/long
4.5.2.8.2
Determine course/speed


4.6
Manage Tracks
4.6.1
Maintain track positions
4.6.2
Correlation/ associate tracks
4.6.3
Maintain track database
4.6.4
Report Tracks


4.7
Analyse Tactical Picture
4.7.1
Determine contact threat level
4.7.2
Ensure all tracks accounted for
4.7.3
Delete contacts as required


4.8
Refine automated processes
4.8.1
Evaluateautomated processes
4.8.2
Adjust parameters